Meteorological Office

Annual Report 1977

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ANNUAL REPORT

ON THE

METEOROLOGICAL OFFICE

1977

Presented by the Director-General
to the
Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE

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Cover photograph: The Hercules of the Meteorological Research Flight viewed from the BAC 111 *of the Royal Aircraft Establishment (photograph by the RAE Photographic Section)*

FOREWORD BY THE DIRECTOR-GENERAL

This *Annual Report* for 1977 gives, in more detail than before, information on the expenditure and revenue of the Office and contains a special article on the revenue services, the income from which, during the current financial year, will be about £8·75 million, nearly one-third of our total expenditure.

The demand for weather forecasts, information and advice of all kinds continues to grow. The number of direct enquiries to forecasting offices reached a new record total of 1·97 million, 308 000 of which were received by the London Weather Centre. In addition, 2·18 million forecasts were made for civil and military aviation, also a new record, and 19·04 million calls were made on the automatic telephone weather service (ATWS) compared with 16·25 million in 1976.

The Office is making special efforts to publicize its services to industry by special displays and exhibitions, the most ambitious of which, in 'Offshore Europe 77' in Aberdeen, attracted a great deal of interest and new business. Special efforts are being made to meet the increasing demands of the offshore industry, including its helicopter support operations, and to assist oil-tanker operations inshore. A new forecasting office is being established at Lerwick in Shetland to support the operations of large tankers using the Sullom Voe oil terminal and temporary offices were established on site and at short notice to help with particularly difficult phases in the building, flotation and towing of giant structures. A wave-forecasting model, supplied with forecast winds from the high resolution atmospheric model and taking into account the effects of water depth and sea-bed friction, has been developed for operational use next year and will be particularly useful for predicting waves and swell in the North Sea.

Some interesting examples of the 29 000 enquiries handled by the Climatological Services Branch during the year concerned:

> The risks of strong winds, frozen spray and sea-ice likely to affect the tow of a barge from Teesside to Tomsk; extreme wave heights for major construction projects in Libya, Japan and the Gulf of 'Aqaba; visibilities in the Red Sea and the West Indies affecting the design of lighthouses; extreme wind speeds affecting the design of masts on Mount Olympus; intense rainfalls affecting storm drainage systems in Yemen (People's Democratic Republic).

The computer models which provide basic guidance for the daily weather forecast have undergone further development with improved treatments of long-wave radiation, the underlying land and sea boundaries, and of topography, and steps have been taken to include 'off-time' and unconventional observations from aircraft, satellites etc. It was particularly gratifying that our work on numerical weather prediction was included in the Royal Society Silver Jubilee Exhibition which demonstrated twelve of the most important British contributions to science during the Queen's reign.

Although dynamical models have produced marked improvements in the accuracy of forecasts for 24–72 hours ahead, they have done little to improve the predictions over the first 12 hours when the weather is often dominated by small-scale systems which cannot be represented explicitly in current models. Although higher resolution models are being developed, early improvements

are more likely to result from extrapolation of the movement and development of precipitation patterns as observed by radar and satellite pictures. An experimental mini-network of three radars is now being installed at Camborne, Clee Hill and Upavon. The digitized output of these radars will be composited to form a single map with rainfall intensities shown in eight colours on a television screen that may be updated every few minutes. The information will be transmitted to the Radar Research Laboratory at Malvern and later to the Gloucester forecasting office where a special short-range forecasting unit will be established to exploit the technique in conjunction with satellite pictures received at Lasham. The first radar (Camborne) should be operational in April 1978 and the network may be expanded later to incorporate radars in Lancashire and possibly Jersey and London. In order to be of maximum use such short-range forecasts must be rapidly disseminated to the customer and we are collaborating with the Post Office in the use of their Viewdata system for this purpose.

The accuracy of weather forecasts largely depends on an adequate supply of observations and here there is some cause for concern. Our own national network of surface stations has been considerably reduced over the years by the closure of RAF bases and has serious gaps which are being partly filled by automatic stations. Problems with the new Mark 3 radiosonde system have at last been overcome. The first station, Aughton, became fully operational in November. Crawley should be operational next February and thereafter the remainder of the stations will be commissioned at roughly monthly intervals and the whole program completed early in 1979. The withdrawal of the US ocean weather ships still leaves a large gap in the western Atlantic but the four eastern Atlantic stations continue to operate satisfactorily. The best two of our 33-year-old ships have been very successfully refurbished and should last for several more years. They are now equipped with the new NAVAID wind-finding system, replacing the old radar tracking technique.

The first European geostationary satellite (METEOSAT), built and operated by the European Space Agency, was successfully launched in November. It is now in position over the intersection of the equator and the Greenwich meridian and is already providing excellent pictures (see Plate I) of cloud systems which are received through the station at Lasham. In the near future we can look forward to data on winds, sea surface and cloud surface temperatures etc. that should prove of great value for research and forecasting purposes.

In highlighting a few of our many research activities, the following merit special mention this year.

Much effort has gone into equipping the Hercules aircraft of the Meteorological Research Flight for the comprehensive study of clouds. The work of the Flight is described in the Special Topic on page 71.

Numerical models of the global atmospheric circulation have been further developed and improved to allow the simulation of long-period climatic changes. In particular, representations of the upper layers of the oceans are now being included, and the surface moisture over land and the extent and depth of the snow cover which interact with the atmosphere to produce important feedback effects, are being modelled more realistically. The models have been used to assess the effects on the atmosphere of anomalies in ocean surface temperatures, to simulate and predict the south-east Asian summer monsoon, and to assess the effects of developments in one hemisphere on those in the other.

Attempts to forecast the general character of the weather over a month by running a model for up to 50 days and averaging the results over 10-day periods have been encouraging and hold some promise that these methods may ultimately replace the present empirical analogue methods. Advances have been made in predicting the dispersion and ground-level concentrations of pollutants downwind from elevated or ground-level sources in terms of the wind, cloud cover, nature of the terrain and time of day.

This has been a very successful year for graduate recruitment; 15 high-quality graduates, 4 with research experience, were selected from more than 500 candidates.

Recruitment of Assistant Scientific Officers was resumed on a modest scale after an interval of 2 years. There was no shortage of suitable applicants but the intake fell short of target because an unexpectedly large number declined offers of appointment. This should be corrected in 1978 but the long-term position will need watching as large numbers of ASOs will be required over the next decade.

B. J. MASON

February 1978
Meteorological Office
Bracknell, Berks.

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FUNCTIONS OF THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

The general functions of the Meteorological Office are:

(a) The provision of meteorological services for the Army, Royal Air Force, civil aviation, the merchant navy and fishing fleets; provision of basic meteorological information for use by the Royal Navy; and liaison with the Director of Naval Oceanography and Meteorology.

(b) The provision of meteorological services to other government departments, public corporations, local authorities, the Press, television, radio, industry and the general public.

(c) The organization of meteorological observations, including observations of radiation, atmospheric electricity and ozone, in the United Kingdom and at certain stations overseas.

(d) The collection, distribution and publication of meteorological information from all parts of the world.

(e) The maintenance of the observatories at Kew and Lerwick.

(f) The provision of professional training in meteorology.

(g) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization, and acts in concert with the other Directors of the Meteorological Services in Western Europe in the co-ordination of their program.

COMMITTEES

METEOROLOGICAL COMMITTEE

Terms of reference:

(a) To keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy.

(b) To keep under review the general scale of effort and expenditure devoted to the meteorological services.

(c) To ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

Membership at 31 December 1977:

Chairman: The Earl of Halsbury, F.R.S.

Members: Dr J. Birks, C.B.E.
Professor A. H. Bunting, C.M.G.
Sir Frederic Harmer, C.M.G.
Professor J. T. Houghton, F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)

Secretary: Mr A. C. Hughes (Secretary, Meteorological Office)

The Committee met three times in 1977.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

(a) To review the development of meteorological science and its application to Scotland.

(b) To submit to the Meteorological Committee any proposal in connection therewith.

Membership at 31 December 1977:

Chairman: Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)

Members: Mr S. C. Agnew (Scottish Development Department)
Mr R. J. H. Brush (University of Dundee)
Dr H. E. Butler, F.R.S.E. (Royal Society of Edinburgh)
Dr J. M. Caborn (University of Edinburgh)
Sir Samuel C. Curran, F.R.S.
Professor S. Desmond Smith, F.I.P., F.R.S.E. (Heriot-Watt University)
Mr H. D. Dooley (Department of Agriculture and Fisheries for Scotland)
Mr J. Ferguson (Department of Agriculture and Fisheries for Scotland)
Professor G. M. Howe (University of Strathclyde)
Mr R. Lines (Forestry Commission)

Dr D. H. McIntosh, F.R.S.E. (Department of Meteorology, University of Edinburgh)
Councillor W. J. McKechin (Convention of Scottish Local Authorities)
Professor H. Meidner (University of Stirling)
Dr I. S. Robertson (University of Aberdeen)
Professor D. W. N. Stibbs, F.R.S.E. (University of St Andrews)
Professor P. A. Sweet (University of Glasgow)

Secretary: Mr J. S. Hopkins (Meteorological Office)

The Committee met once in 1977.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Parliamentary Under-Secretary of State for Defence for the Royal Air Force on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint subcommittees, one of which shall be responsible for advising on the use of money allocated annually from Defence Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its subcommittees.

Membership at 31 December 1977:

Chairman: Professor J. T. Houghton, F.R.S.

Members: Instructor Captain R. K. Alcock, R.N. (Director of Naval Oceanography and Meteorology)
Professor R. L. F. Boyd, C.B.E., F.R.S.
Mr J. Burnham (Procurement Executive, Ministry of Defence)
Professor H. Charnock, F.R.S.
Mr G. A. Corby (Director of Services, Meteorological Office)
Professor D. R. Davies
Mr A. Gilchrist (Deputy Director, Dynamical Research, Meteorological Office)
Mr P. Goldsmith (Deputy Director, Physical Research, Meteorological Office)
Professor J. Latham
Wing Commander D. M. Leslie (Air Force Department)
Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)
Mr D. E. Morris (Civil Aviation Authority)
Professor R. P. Pearce, F.R.S.E.
Mr J. S. Sawyer, F.R.S.
Dr K. H. Stewart (Director of Research, Meteorological Office)
Dr P. F. G. Twinn (Natural Environment Research Council)

Secretary: Mr R. A. Ebdon (Meteorological Office)

The Committee met twice in 1977 and its subcommittees seven times.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

B. J. Mason, C.B., D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

G. A. Corby, B.Sc.

DIRECTORATE OF SERVICES

DIRECTOR	G. A. Corby, B.Sc.
INTERNATIONAL AND PLANNING Assistant Director	G. J. Day, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR	F. H. Bushby, B.Sc., A.R.C.S.
CENTRAL FORECASTING Assistant Director	D. E. Jones, M.Sc., D.I.C., A.R.C.S.
DEFENCE SERVICES Assistant Director	I. J. W. Pothecary, B.Sc., M.Inst.P.
Chief Meteorological Officer, H.Q. Strike Command	J. C. Gordon, M.A.
PUBLIC SERVICES Assistant Director	D. H. Johnson, M.Sc., D.I.C., A.R.C.S.
Chief Meteorological Officer, London/Heathrow Airport	A. Ward

COMMUNICATIONS AND COMPUTING

DEPUTY DIRECTOR	M. J. Blackwell, M.A.
TELECOMMUNICATIONS Assistant Director	D. McNaughton
DATA PROCESSING Assistant Director	G. A. Howkins, M.B.E., B.Sc.
SYSTEMS DEVELOPMENT Assistant Director	E. J. Sumner, B.A.

OBSERVATIONAL SERVICES

DEPUTY DIRECTOR — N. E. Rider, D.Sc.

Observational Requirements and Practices

Assistant Director — D. R. Grant, B.Sc.
Marine Superintendent — G. A. White, Captain, Extra Master

Climatological Services

Assistant Director — R. J. Ogden, B.Sc.

Agriculture and Hydrometeorology

Assistant Director — C. V. Smith, M.A., B.Sc.

Operational Instrumentation

Assistant Director — D. N. Axford, Ph.D., C.Eng., M.I.E.E.

DIRECTORATE OF RESEARCH

DIRECTOR — K. H. Stewart, Ph.D.

PHYSICAL RESEARCH

DEPUTY DIRECTOR — P. Goldsmith, M.A.

Geophysical Fluid Dynamics Laboratory

Head of Branch — R. Hide, Sc.D., F.R.S.

Boundary Layer Research

Assistant Director — F. B. Smith, Ph.D.

Meteorological Research Flight

Chief Meteorological Officer — D. G. James, Ph.D.

Meteorological Office Radar Research Laboratory

Chief Meteorological Officer — K. A. Browning, Ph.D., D.I.C.

Cloud Physics

Assistant Director — P. Ryder, Ph.D.

High Atmosphere

Assistant Director — D. E. Miller, B.A.

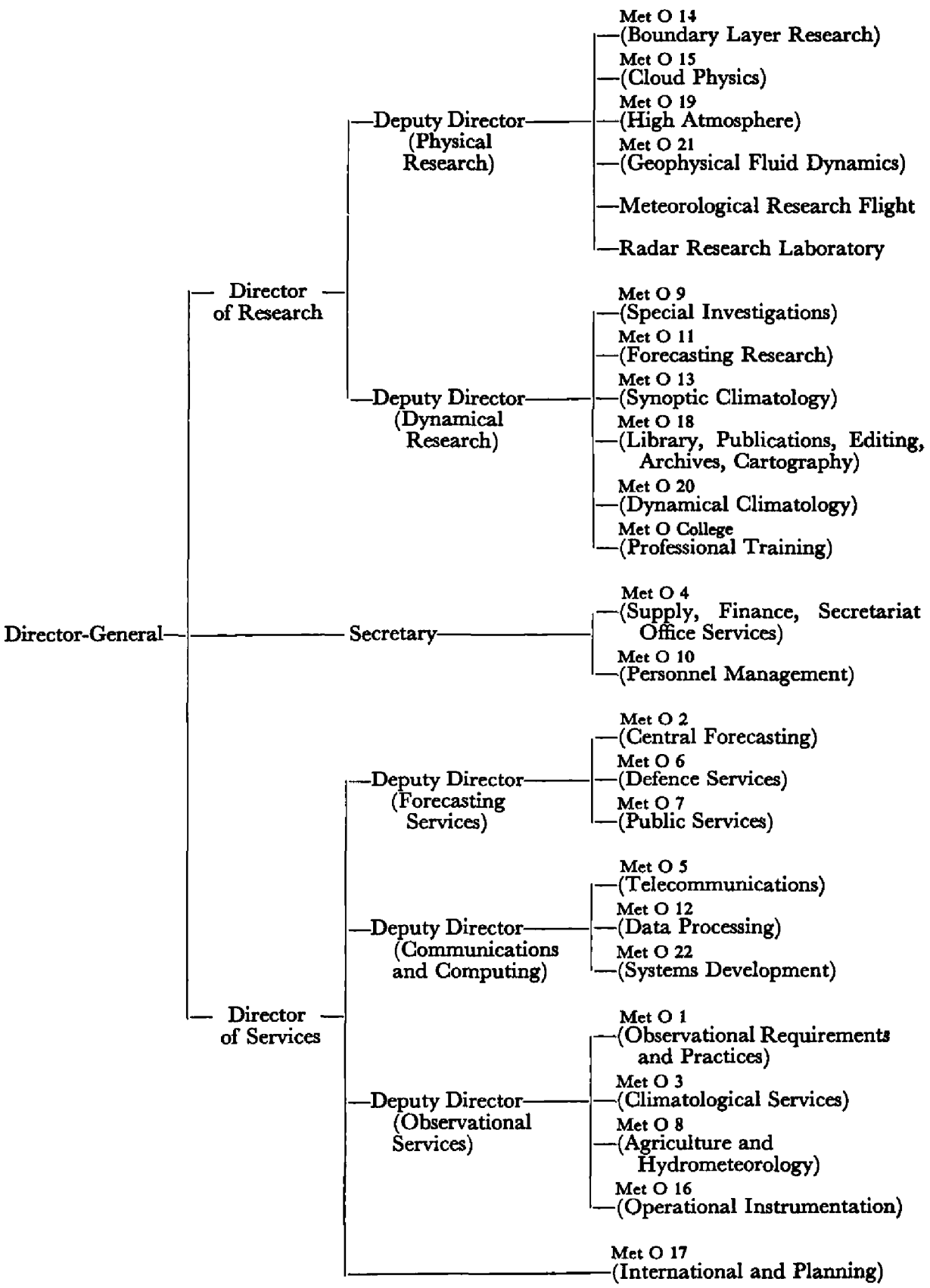
DEPUTY DIRECTOR	A. Gilchrist, M.A.
SPECIAL INVESTIGATIONS	
Assistant Director	W. T. Roach, Ph.D., D.I.C.
FORECASTING RESEARCH	
Assistant Director	P. W. White, Ph.D.
Special Post	R. Dixon, B.Sc.
SYNOPTIC CLIMATOLOGY	
Assistant Director	D. M. Houghton, M.Sc., D.I.C.
PROFESSIONAL TRAINING	
Assistant Director and Principal, Meteorological Office College	S. G. Cornford, M.Sc.
DYNAMICAL CLIMATOLOGY	
Assistant Director	P. Graystone, B.A.
Special Post	R. J. Murgatroyd, O.B.E., Ph.D., C. Eng., M.I.E.E.

ADMINISTRATION, FINANCE AND SUPPLY

SECRETARY, METEOROLOGICAL OFFICE	A. C. Hughes, M.Sc., M.Phil.
PERSONNEL MANAGEMENT	
Assistant Director	F. Singleton, B.Sc., D.I.C.

METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

(at 31 December 1977)


Director-General
Director of Research
Deputy Director (Physical Research)
Met O 14 (Boundary Layer Research)
Met O 15 (Cloud Physics)
Met O 19 (High Atmosphere)
Met O 21 (Geophysical Fluid Dynamics)
Meteorological Research Flight
Radar Research Laboratory
Deputy Director (Dynamical Research)
Met O 9 (Special Investigations)
Met O 11 (Forecasting Research)
Met O 13 (Synoptic Climatology)
Met O 18 (Library, Publications, Editing, Archives, Cartography)
Met O 20 (Dynamical Climatology)
Met O College (Professional Training)
Secretary
Met O 4 (Supply, Finance, Secretariat Office Services)
Met O 10 (Personnel Management)
Director of Services
Deputy Director (Forecasting Services)
Met O 2 (Central Forecasting)
Met O 6 (Defence Services)
Met O 7 (Public Services)
Deputy Director (Communications and Computing)
Met O 5 (Telecommunications)
Met O 12 (Data Processing)
Met O 22 (Systems Development)
Deputy Director (Observational Services)
Met O 1 (Observational Requirements and Practices)
Met O 3 (Climatological Services)
Met O 8 (Agriculture and Hydrometeorology)
Met O 16 (Operational Instrumentation)
Met O 17 (International and Planning)

DIRECTORATE OF SERVICES

Special Topic—Meteorological Office Revenue-producing Services

Although the greater part of the Meteorological Office's effort continues to be devoted to Defence needs, the demand for meteorological services from elsewhere has increased substantially in recent years. For example, forecast enquiries (including aviation) rose from 2·6 million a year in 1967 to 4·1 million in 1977. Over the same period, the annual number of climatological enquiries rose from 12 533 to 28 986. In addition, increasing use was made of the automatic telephone weather service (ATWS) to which 19·0 million calls were made in 1977. The figures for each year from 1967 to 1977 were as follows:

Table 1—growth in the number of enquiries

Year	ATWS	Forecast Enquiries			Climato-logical enquiries
		Special seasonal*	Aviation	Other (non-aviation)	
1967	7 599 241	847	1 335 335	1 264 605	12 533
1968	10 016 877	894	1 345 368	1 480 262	13 610
1969	12 401 471	825	1 446 223	1 610 484	13 813
1970	13 251 614	772	1 468 616	1 633 478	14 498
1971	11 544 411	708	1 399 526	1 535 523	13 553
	Note 1			*Note* 1	*Note* 1
1972	12 860 788	672	1 531 545	1 582 129	15 269
1973	15 501 162	661	1 527 710	1 745 888	17 046
1974	16 255 932	540	2 074 855	1 854 387	19 561
1975	16 935 351	505	2 183 935	1 840 820	23 077
1976	16 250 683	500	2 156 639	1 865 050	26 126
1977	19 040 617	490	2 176 114	1 973 002	28 986
		Note 2		*Note* 3	*Note* 4

*Includes dry-spell notifications, week-end temperature forecasts, and winter road-danger warnings.

Notes

1. Reduction attributed to Post Office strike.
2. Progressive reduction mainly in dry-spell forecasts for farmers (425 in 1969, 137 in 1977); (attributed to better routine forecasts giving outlook for next day or two, and Sunday TV forecast of week's weather for farmers).
3. Categories include: Holidays (376 500), Marine (192 428), Agriculture (257 374), the Press (196 192), Public utilities (170 452) and Transport (141 099).
4. Categories include: Building (7628), Legal (3687), Water authorities (2358) and Agriculture (2601).

During that time, thanks largely to the extensive use of computers and automated telecommunication systems, it has been possible to meet this considerably increased demand, and to improve the quality of the service offered, with little or no real increase in overall gross expenditure. Table 2 shows gross expenditure for each of the financial years 1969/70 to 1977/78, both as it was estimated at the time and as adjusted to 1977/78 pay and prices. The latter figures show a slow rise in real expenditure over the early part of the period, followed by a levelling-off and a recent decline.

It is necessary to treat these figures with some caution. The only financial information available for the early years of the period are those in annual Defence Estimates prepared shortly before the year in question. In looking for

TABLE 2—ESTIMATED EXPENDITURE AND CORRESPONDING ADJUSTED FIGURES

Year	Estimated gross expenditure	Gross expenditure adjusted to 1977/78 pay and prices
	Thousands of pounds	
1969/70	9 300	28 400
1970/71	10 400	28 400
1971/72	11 800	29 500
1972/73	13 800	31 500
1973/74	15 000	30 700
1974/75	18 000	31 700
1975/76	21 600	30 900
1976/77	27 200	31 600
1977/78	28 200	28 200

a trend it has been necessary to use this basis throughout. The figures, and those in Table 3 below, are not therefore strictly comparable with those quoted elsewhere in this and previous *Annual Reports*. The Office is in the process of improving and extending its management accounting system and in future years more accurate historic costings should be available for exercises of this nature.

As part of the Ministry of Defence, the Meteorological Office is expected to make its contribution to planned reductions in Defence expenditure. If, therefore, it is to continue to meet demands for its services and improve its high technical standards, the Office will need to expand its revenue-earning business. This will have the added advantage of directing the Office's attention to those areas where meteorological advice is likely to be of direct benefit—on the not unreasonable assumption that willingness to pay is a measure of need—and the pressure to keep down the cost of price-sensitive work is an added incentive to improve efficiency. This would not be a new departure for the Office but merely a reinforcement of present trends. In spite of substantial obstacles—not the least of which are the high overheads inevitably associated with the collection, transmission and processing of millions of observations from much of the northern hemisphere, and a century-old tradition of providing a free general forecast—the Office's record in developing revenue-producing services in recent years has been encouraging, as is shown in Table 3.

TABLE 3—ESTIMATED RECEIPTS AND THEIR PROPORTION OF GROSS EXPENDITURE

Year	Estimated receipts	Estimated receipts adjusted to 1977/78 pay and prices	Receipts as percentage of gross expenditure
	Thousands of pounds		*Per cent*
1969/70	2000	6120	21·5
1970/71	2400	6540	22·6
1971/72	2700	6760	22·9
1972/73	2800	6390	20·4*
1973/74	2900	5810	19·0*
1974/75	4000	7050	22·2
1975/76	4800	7050	22·8
1976/77	7000	8280	26·0
1977/78	8750	8750	31·0

*The fall in receipts in these years is attributed to the price freeze and the abolition of Selective Employment Tax.

The table shows that, over the period, receipts increased both in real terms and as a percentage of gross expenditure, thus reflecting a decreasing dependence on Defence Votes. The trend can be seen most easily in Figure 1.

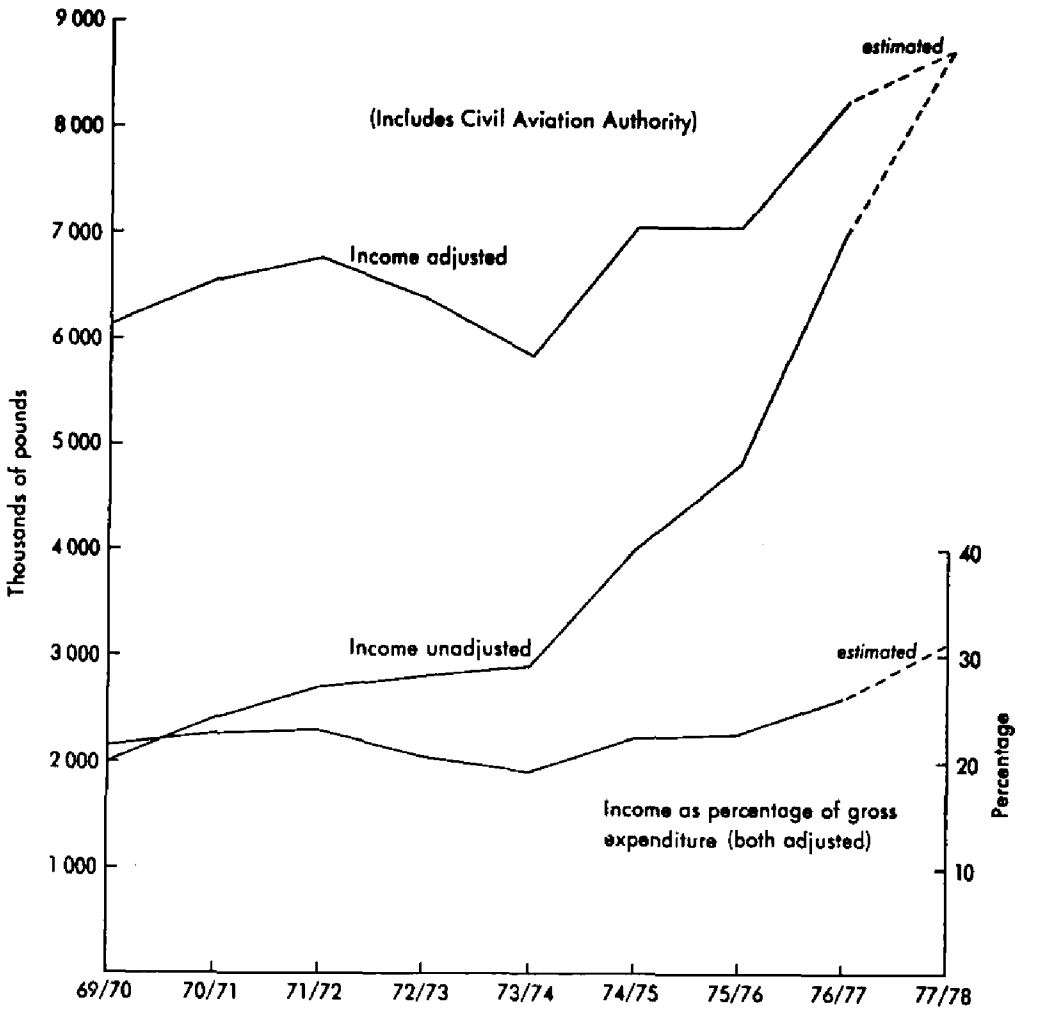


Figure 1—Income (adjusted and unadjusted) for the financial years 1969/70 to 1977/78, also expressed as a percentage of gross expenditure

Non-aviation receipts

A substantial part of the Office's total income is derived from services to civil aviation. These are likely to decline in future years as commercial flying becomes less weather-sensitive and it will therefore be necessary to look to non-aviation sources for any increase in revenue. Although the Office does not have an entrepreneurial tradition and is not organized or staffed so as to maximize the commercial exploitation of its services, it has done what it can to publicize the services it can offer to commerce and industry through direct contact with commercial organizations and with Government departments concerned with industry, through articles, papers and selective advertisements in the Trade Press, through membership of national and international committees, by publishing papers, memoranda and books, and by publicizing successful commercial efforts within the industries concerned, and also in the media whenever opportunity offers. The Public Services Branch of the Office has recently

produced a number of brochures aimed at publicizing and expanding such services (see page 13) and these have been well received.

This publicity drive has coincided with an upsurge in the highly weather-dependent offshore oil and gas industries, with the result that there has been a dramatic increase in income from non-aviation sources, particularly in recent years. As Figure 2 shows, this income has increased by an estimated 700 per cent over the 8-year period.

The Office has been particularly successful in providing a service to the offshore industry in the face of competition from commercial weather consultants. A team of senior forecasters at the London Weather Centre, with long experience of forecasting for the British Isles and the continental shelf, has built up a considerable expertise in this field. Recently a full-time meteorological consultant for the offshore industry has been established at the Offshore Supplies Office in Aberdeen, and a new meteorological office building is being opened at Sumburgh Airport in Shetland to provide tailored forecast services for helicopter flights serving the oil rigs etc. All these efforts are supported by a vigorous and specialized research program. However, it would be wrong to assume that there has been uniform growth in all our revenue-producing services. The rise in income shown in Figure 2 is due partly to a rise in the

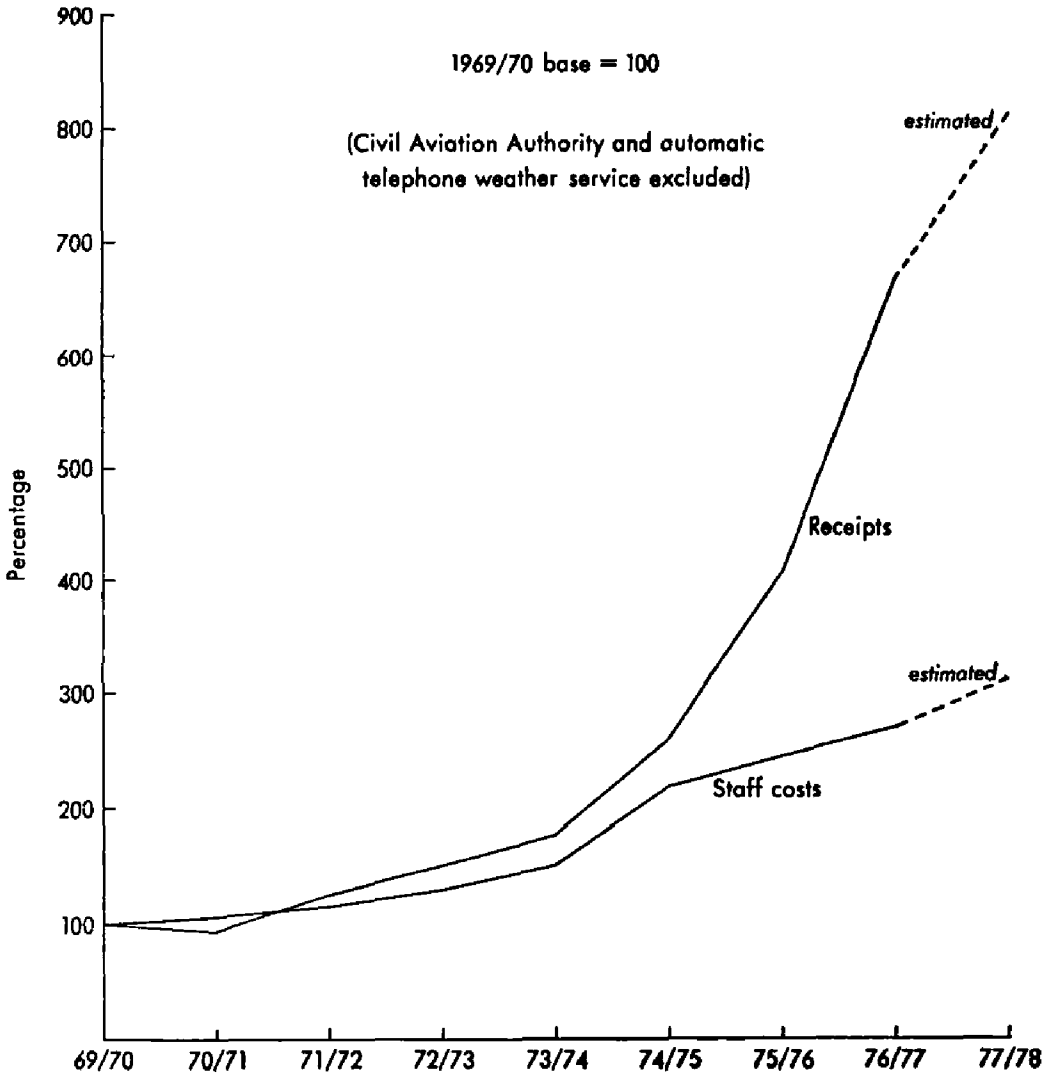


Figure 2—Index of receipts and staff costs for repayment work, 1969/70 to 1977/78

volume of business and partly to a more realistic charging policy, resulting in the allocation of a greater share of overheads than before to these particular services. This latter factor, combined with a high rate of inflation, actually led to a marked drop in the total volume of business between 1974/75 and 1975/76 although, fortunately, there has been a substantial recovery since then, as shown in Figure 3.

Although the combination of circumstances which led to the fall between 1974/75 and 1975/76 is unlikely to recur, the graph in Figure 3 does show the extreme sensitivity of some of our services to price levels, and the difficulties with which the Office is faced in seeking to push up the proportion of expenditure which comes back by way of revenue. Given that more than half of the work of the Services Directorate is devoted to Defence, it is most unlikely that revenue could ever exceed 40 per cent of gross expenditure even if a fairly substantial switch of resources from 'free' services to those which earn revenue were to be socially acceptable. Indeed, given the probable reduction in income from civil aviation, a ceiling of 35 per cent would be more realistic.

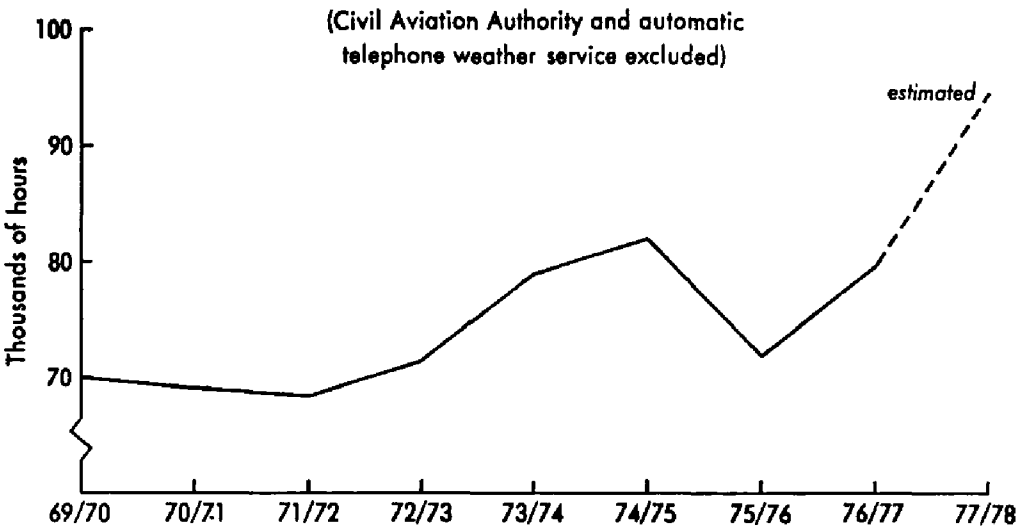


Figure 3—Work done on repayment services, 1969/70 to 1977/78

Range of services provided

As well as reports, forecasts and warnings of weather conditions, the Meteorological Office provides advisory services on all aspects of climatology, rainfall and evaporation, agricultural and marine meteorology, and meteorological instrumentation and techniques; (the sale and lease of equipment, charges for training, or the loan or secondment of meteorological staff, represent not inconsiderable elements of the Office's revenue).

Specialized services provided by the Office fall into three main categories:

(a) Weather reports, forecasts or warnings for a particular locality, or of specified weather, or otherwise tailored to meet the special needs of the customer.

(b) The study of records of past weather and the preparation and interpretation of summaries and statistical analyses of the weather in a particular locality or season for a particular purpose or activity. Individual consultation and special investigations can often be arranged.

(c) Training, and the sale or loan of photographs, books, films and equipment.

The range of customers prepared to pay for such meteorological services is already very wide and covers the following varied interests.

Agriculture. Individual farmers and fruit-growers receive forecasts of dry spells, frosts etc. In conjunction with the Ministry of Agriculture, Fisheries and Food, which contributes to the cost, research is conducted into the relationships between weather factors and animal or plant diseases and infections. Weather summaries have also been provided to organizations forecasting crop yields, as part of an economic commodities service, and climatological information has been used to determine the commercial viability of particular crops in specific areas.

British Rail and London Transport. Both receive warnings of particular weather conditions which would affect their operations.

Confectionery and frozen-food manufacturers. They receive temperature forecasts to help avoid deterioration when transporting their goods in hot weather.

Construction industry. It makes many and varied uses of meteorological forecasts and warnings in connection with the building of motorways, yacht marinas, factories and offices, and also with drainage and irrigation projects. The successive prolonged dry and wet spells in 1976 produced a marked upsurge in requests for statistical information, and a recent new development has been the considerable demand from consulting engineers, architects and others in Britain for climatic information on overseas countries, particularly the oil-producing countries in Africa and the Middle East. The Department of the Environment has financed special programs of research into the effects of high winds on bridge and building structures, and the effect and amount of driving rain on buildings.

Electricity and gas industries. These continue to require forecasts of wind and temperature so as to gear production economically to meet expected demand. Special forecasts have also been given for gas pipeline laying operations. A climatological study has been made to help the Central Electricity Research Laboratories to determine maximum currents that can be carried by exposed national-grid cables under extremes of weather conditions.

Ice-cream manufacturers. They require temperature forecasts to enable them to predict demand for their products.

Legal and insurance matters. Certified statements of past weather may be required or the attendance of meteorological staff to give expert evidence on weather conditions etc.

Local authorities. They are provided with road-danger warnings of freezing conditions or of snow and may require other special services, such as warnings of strong winds in an area where houses have been weakened by subsidence.

Industrial concerns. A variety of services is required, tailored to special needs, but many require regular forecasts of temperature and wind to help in their energy conservation programs.

Pigeon-racing interests. Forecasts are provided for specified routes for the duration of a race, with special attention paid to factors known to affect the performance of the birds.

Shipping companies. There is still a steady demand for the specialized weather-routeing service for ships in the Atlantic and the Pacific.

Water authorities. They have shown an increasing interest in hydro-meteorological information for drainage schemes, flood prevention measures, water supply etc.

Future developments

One of the major difficulties which the Office faces in seeking to achieve its full revenue-earning potential is that of recovering small costs economically from a multitude of users, and it is principally for this reason that large numbers of casual enquiries continue to be dealt with free of charge. The automatic telephone weather service (ATWS) was developed to reduce the load on the Office from such casual enquiries, but as it is not possible to add an element to the cost of a telephone call to cover the meteorological input, only a token sum is received from the Post Office for this service. However, the advent of teletext (the transmission of information from a computer data-bank to a television screen), particularly the Post Office Viewdata system, offers the possibility of communicating a much greater variety of weather information than can be disseminated through ATWS or traditional radio and television presentations, while permitting recovery of a charge from the industry, organization or individual making use of it. The Office is therefore actively assisting the Post Office in the assessment of the commercial potential of its system (see page 12). The opportunity that teletext offers for the rapid dissemination of meteorological information provides another incentive for the development of techniques for the production of more accurate short-range weather forecasts (those for periods up to 6 hours ahead). Because of the economic benefits that these offer to a wide variety of users, part of the research program of the Office is being directed to these ends (for example, research into the potential of a radar network for the measurement of rainfall over a wide area with automatic processing and presentation of data). Increased effort is also being devoted to the improvement of repayment services in the fields of hydrometeorology (principally for legal matters, water authorities, commercial undertakings and constructional engineering) and climatology for which the Office has vast quantities of data going back over very many years.

Forecasting Services

Central Forecasting Office

As the chief forecasting centre of the Meteorological Office, the Central Forecasting Office (CFO) fulfils three main requirements:

(a) It provides guidance to outstations of the Office; this guidance is mainly in the form of charts of plotted observations, charts depicting actual and forecast synoptic situations, and advisory texts covering the next three days. They are disseminated by land-line facsimile and teleprinter transmissions.

(b) CFO is also responsible for routine forecasts for sea and land areas and for warnings of hazardous weather conditions such as gales, fog, snow, frost, icy roads, thaw and thunderstorms over the United Kingdom. These forecasts are intended for dissemination by the Press, radio and television, but some are issued direct to public utilities such as the British Gas Corporation and the Central Electricity Generating Board.

(c) At the international level, CFO is a Regional Meteorological Centre in the World Weather Watch plan of the World Meteorological Organization and serves the needs of a number of National Meteorological Centres in Europe for regional forecasts and guidance covering a large area of the North Atlantic, Europe and the Arctic. This guidance is mostly in the form of charts which are broadcast by radio-facsimile or in coded form by radio-teleprinter.

Analyses and forecasts are produced in CFO by a combination of numerical (computer) methods and subjective (manual) methods. The observational data are processed by computer which also provides analysis and forecast guidance for the forecasters; the forecasters monitor these processes, modifying the products in the light of their own synoptic experience, their knowledge of the systematic behaviour of the numerical analysis and forecast models, and by considering information not available to the basic data set used in the numerical system. This information may consist of observations that have been received too late to be included in the numerical operational system and data that have been inferred from the satellite picture, especially those concerning humidities.

The two versions of the 10-level numerical forecasting model (the course-mesh octagon version covering most of the northern hemisphere, and the fine-mesh rectangle covering Europe and much of the North Atlantic) continue to provide the basic computer-forecasting guidance. The split-explicit time-integration scheme, introduced in 1976, has been used throughout the year for the octagon forecasts, and verification statistics indicate an improvement in accuracy of these numerical forecasts. The method has now been incorporated in the rectangle forecast model and this is undergoing tests. Further refinements to the 10-level model, including a long-wave radiation scheme, a revised lower boundary condition and a more realistic treatment of topography, have been tested for operational use. Both versions of the model have been run twice a day from analyses based on observations for 00 and 12 GMT, but towards the end of the year the rectangle version, which is used to provide guidance on rain forecasting, has also been run experimentally from 06 GMT data. This enables the numerical forecast system to make use of the synoptic data for 06 GMT and the asynoptic data between 03 and 09 GMT. It thus provides the Senior Forecaster with guidance, based on recent data, in time for him to give it full consideration before he commits himself in the afternoon forecasts.

Probably the biggest change in CFO derives from the considerable development of computer terminal facilities now available. As a result of close liaison between CFO and the computer support section of the branch there has been a great increase in the efficiency of data monitoring. The computer is used to identify dubious observations and present them on two visual display units (VDUs) in CFO where the forecasters can use their judgement and direct the computer to reject or accept the observations or amend them in some way. The VDUs are also used for displaying the computer analyses and forecasts, and the two-way interaction between forecaster and computer can take place at the analysis stage.

The forecasters in CFO, particularly the Senior Forecaster who is responsible for doing most of the surface analyses, for constructing forecast surface charts and for forecasting weather over the British Isles, have to survey and digest a large amount of information of many types. This includes surface and upper-air observations, sequences of analysed surface charts, the related upper-air charts, tephigrams and satellite pictures, as well as computer analyses and forecasts. Consequently a lot of effort has been devoted to the presentation of computer output in a convenient and readily assimilable form.

Preparations have also gone ahead for greater use of the computer-controlled chart-plotting machines sited in the Computing Laboratory. The operational implementation of this work will lead to a reduction in the number of staff employed on plotting charts, both for use in CFO and for transmission by fac-

simile. The manual plotting itself is also being made more efficient by the installation of Transtel 'silent' teleprinters at each plotting bench. The teleprinters are controlled by the communications computer system and they bring to each plotting bench exactly the data that are required, and no more. This has eliminated much manual sorting of paper and reduced staff movement around the forecast room.

A major task of the computer support section is the maintenance of the operational suite of programs which is frequently being modified to cope with changes in international codes, station numbers or changes to the COSMOS system. The section has tackled a large variety of operationally oriented work in addition to those already mentioned, and every effort is made to make full use of the facilities provided by the Computing Laboratory. Investigations continue on the use of novel humidity data and on the impact of different humidity analyses on the rectangle forecasts. Work has been started under a contract with Eurocontrol on ways of making best use, for aircraft control purposes, of frequent reports of winds and temperatures from civil aircraft in flight. The procedures for verifying forecasts against observations have been completely rewritten and expanded and a new verification scheme for surface pressure charts, based on objective classification of weather types, has been developed.

In 1976 the issue of forecast guidance for two and three days ahead was increased to twice daily and this routine was continued in 1977 because of the importance of these forecasts to agricultural, industrial and manufacturing interests as well as to the general public. They are of particular interest to offshore operators engaged in weather-sensitive work such as pipe-laying, oil and gas rig installation, and the maintenance of supply services to such rigs and platforms. Forecast charts are also regularly produced for four and five days ahead to help formulate extended outlooks, especially for farming and the offshore industry. Their distribution is limited, however, and the verbal guidance based on them is expressed in very general terms because, although the extended numerical forecasts on which they are based are slowly being improved and show considerable skill, further improvement is still desirable.

The forecasting of sea waves and swell up to 48 hours ahead for the North Atlantic continues to be a commitment for international broadcasts and for use by the Meteorological Office ship-routeing service. The charts of forecast wave height and movement are produced subjectively by the Medium-range Forecaster but he now has as guidance computer-produced forecasts which are based on the winds output by the octagon version of the 10-level model. A wave-forecasting numerical model, based on the fine-mesh area and taking into account the effects of water depth on the group velocities and bottom friction, has been implemented in a diagnostic mode and it is hoped that it will be run in operational forecasting mode next year; it will be particularly useful for wave and swell forecasting in the North Sea. Considerable interest was shown in the model at international meetings at Hamburg and Marseilles; the numerical techniques used are rather unusual in this field.

Cloud photographs from the United States weather satellites (mostly NOAA-5, including very high resolution segmental pictures) received at Bracknell are a valuable aid to the preparation of surface analysis over the North Atlantic and European area. The Systems Development Branch has devised computerized methods for the production of gridded composite pictures on the same scale and projection as is used on the CFO working charts, and

this has greatly facilitated the interpretation of satellite pictures in CFO. Preparations are well advanced for the reception, handling and assessment of pictures and data that will be received from the recently launched geostationary meteorological satellite, METEOSAT (see Plate I).

Under the Area Forecast System of the International Civil Aviation Authority, the aviation forecasters in CFO provide, for domestic and international facsimile circuits four times a day, briefing documentation concerning upper winds and temperatures for flights from western Europe to North America, and for flights from Africa and the Middle East to western Europe. As with most other products they are a result of human modification of computer products. Special forecasts are also made for the Concorde flights to Washington, New York and Bahrain.

A number of changes are in hand in the production of the *Daily Weather Report*, the *Monthly Summary* and the *Daily Aerological Record*. A new Datamatic tape-control typewriter has been installed and the Systems Development Branch has undertaken extensive rewriting of the programs by which the COSMOS computer system punches paper tapes for the production of data tabulations by the typewriters. They took the opportunity to incorporate a number of improvements and the whole procedure is now much more flexible. The Data Processing Branch has written programs for plotting the *Daily Weather Report* charts on the computer-controlled chart plotters and when these programs are put into routine use in 1978 there will be some further reduction in plotting staff.

The Assistant Director (Central Forecasting) continued to serve as a member of the WMO Working Group on the Global Data Processing System (GDPS), one of the Working Groups of the Commission for Basic Systems (CBS). One member of the Branch is the UK member on the Regional Association VI (Europe) Working Group on requirements for GRID code (used for disseminating data in grid-point form). Two others from the Branch are members of the technical advisory group of the NORSWAM project concerned with wave forecasting in the North Sea.

Services for industry, commerce and the general public

Forecasting services for industry, commerce and the general public are provided directly by the Weather Centres and by a number of other forecasting offices, or indirectly through radio, television, the Press, and the Post Office's automatic telephone weather service. Most of the work is undertaken by 34 offices in various parts of the country, whose telephone numbers are published in the prefaces to area telephone directories, in official leaflets and many trade journals. A somewhat greater number of unpublicized offices also attracts requests for advice from industry and the general public.

The upswing in the number of enquiries which followed the ending, in September 1976, of the dry and settled spring and summer weather last year was maintained throughout 1977. Direct enquiries to forecasting offices totalled 1 973 002 in 1977 as against 1 865 050 in 1976, establishing a new all-time record.

Calls on the Post Office's automatic telephone weather service (ATWS) also increased and were maintained at a high level, totalling 19 040 617 in 1977 compared with 16 250 683 in 1976. ATWS forecasts for London and other areas in the south and for areas in the north-west of England are now recorded by staff of the London and Manchester Weather Centres rather than by

members of the Post Office. Special forecasts were supplied to the Post Office in connection with a marine information service in the Swansea telephone area during the summer and for a ski-report service in the Edinburgh area during the winter. Climbers and other visitors to the Lake District can obtain special forecasts by dialling a Windermere telephone number. These have been provided from the Main Meteorological Office at Preston for the Lake District National Park Information Service. A service along similar lines is being planned for the Cairngorm district in Scotland.

The dissemination by television and radio of routine forecasts and warnings continued without major change. However, on BBC Radio 4 there was a reorganization of the early-morning program with the introduction of 'Up to the Hour' and curtailment of the 'Today' program. In each of these programs there is a live contribution by the forecaster, but the question and answer format introduced in 1976 at a little before 0730 and 0830 on week-days was dropped in May 1977 in favour of uninterrupted presentations by the forecaster after the brief news reports at 0735 and 0835. The time allotted on Radio 4 to morning weather forecasts at the week-end was increased with the introduction of two-minute presentations at 0655 and 0755 on Saturdays and at 0755 and 0855 on Sundays, together with a special forecast for sportsmen in 'Sport on 4' at 0843. Another innovation on Radio 4 was the late-night report on the day's weather given at 2357 with a forecast for the following day. The extended weather outlook provided in the Sunday lunch-time BBC 1 Television program for farmers continued to gain in popularity with viewers from all walks of life. The whole of one edition of the program was devoted to the Meteorological Office and its work in support of agriculture and horticulture. Brief weather programs for schools were broadcast on BBC 1 Television programs on Friday afternoons in the autumn. These were devised and presented by the weathermen with the aim of educating schoolchildren in the meaning and use of weather forecasts. Forecasting services were provided to most independent television companies and to local radio stations of the BBC and the Independent Broadcasting Authority. A large number of broadcasts and interviews were given by members of the staff at the request of the various broadcasting authorities; a selection of these is listed in Appendix II (page 124). During the year several visits were made to the Meteorological Office Headquarters at Bracknell by television teams wishing to record various aspects of our work. These came from various departments of the BBC and from Thames and Westward Television.

While free services continued to be provided to the general public with the co-operation of the Press and other media, efforts were made to expand the more highly specialized services which are tailored to individual customers' requirements and are offered on repayment terms. This approach is discussed in more detail in the Directorate of Services Special Topic (page 1). The energy industry is one in which weather forecasting services are seen to be very cost-effective. Forecasts are provided to the British Gas Corporation, for example, on a regional basis every four hours. These include predictions of temperature at two-hour intervals over the next 24 hours with less detailed information for a further two days. Wind and other elements also affect the level of gas consumption. As a result the Corporation is enabled to estimate each day how much gas should be ordered for the following day from the offshore suppliers. Since it can be very expensive for more or less gas to be ordered than is needed, the weather forecasts have considerable economic

significance to this industry. Parallel services are provided for the Central Electricity Generating Board for whom, as well as temperature and wind, the state of the sky (brightness or gloom) is particularly significant as affecting the extent to which people may switch on lights during the day. Meteorological support for the offshore industry is described in a separate section of this report (page 13). Contributions to energy saving were made through the week-end temperature service, which enables industrialists to estimate what heating to leave on in unattended premises, and also by provision of degree-day data for publication by the Department of Energy. The latter are used to enable those responsible for heated buildings to decide whether or not their fuel conservation efforts have been successful.

Many other public authorities, industries and commercial concerns took advantage of the services offered. Warnings were given to highway authorities of road dangers due to weather during the winter months. Services to agriculture and horticulture included, for example, the notifications to fruit-growers of frosts expected in May, and to farmers of dry spells in summer for hay-making or corn harvesting. There was a growing demand for our help from those engaged in outdoor sport or recreation. Yachting, whether on inland waters or inshore, gliding, hang-gliding, ballooning, pigeon racing, horse racing, cricket, outdoor ball games and the like are all affected by the weather and for some of these it is always critical. Details of the many services available are given in *Met. O. Leaflet No. 1* which can be obtained through any meteorological office.

The six Weather Centres are wholly devoted to the service of the general public, commerce and industry. The total numbers of enquiries dealt with by these centres over the past three years were as follows:

	London	Glasgow	Manchester	Southampton	Newcastle	Nottingham
1975	311 354	114 974	121 225	102 298	108 147	61 501
1976	299 160	107 388	117 096	100 342	99 824	62 423
1977	307 539	109 640	132 659	109 700	99 144	65 019

Grand totals: 1975, 819 499; 1976, 786 233; 1977, 823 701.

During 1977, the office formerly known as the Watnall public service office was renamed the Nottingham Weather Centre and the hours of opening of the Manchester Weather Centre were extended to allow full round-the-clock seven-day services to be given. The latter step was necessary because of the closure of the 24-hour meteorological office at Liverpool Airport and the resulting increase in public service work at Manchester.

The means of communication with those requiring forecasting services has hitherto been largely by telephone or by telex. In 1977, however, document facsimile machines, which can be used for transmitting information pictorially via the Post Office telephone network, were installed in the London and Southampton Weather Centres. By this medium actual and forecast weather maps were sent to three Rescue Headquarters of H.M. Coastguard. The Brighton Marina took information in this form from the Southampton Weather Centre, and charts were also sent from Southampton to the Isle of Wight for the briefing of yachtsmen during Cowes week. Other enquiries for services by document facsimile were received and are in various stages of implementation. A communications development of even greater potential is the Post Office Viewdata system. In this a computer, or network of computers, is supplied with data by

information providers and so forms a data bank which can be interrogated via Post Office telephone lines by anyone possessing a suitably modified television set. The Meteorological Office has co-operated with the Post Office in their pilot trials of the system and plans to become a major information provider. A remote terminal linked with the Viewdata computer was installed in October in the Central Forecasting Office.

The Office has taken steps to improve the publicity given to its services and to the uses to which they may be put. It has participated in trade and other exhibitions and displays and has mounted special exhibitions devoted entirely to the work of the Office in the towns and cities in which the Weather Centres are located. These were additional to Weather Centre window displays which are professionally designed and regularly changed. Perhaps the most ambitious display was mounted on the Government stand at the 'Offshore Europe 77' exhibition held in Aberdeen in September. The display was live in the sense that the communications necessary to support a functional office were installed so that an on-the-spot service could be given. The staff of the London Weather Centre manning the exhibit were constantly engaged in dealing with enquiries and the cost of participating was amply covered by the additional contract work generated. The Office also contributed very effectively to the Royal Society Silver Jubilee Exhibition and provided exhibits for the Royal Air Force Cardington 60th Anniversary Exhibition and the Army Air Day held at Middle Wallop. Weather Centre staff arranged exhibitions in the Rates Hall of the Newcastle Civic Centre, the Cleveland Centre in Middlesbrough, the Arndale Centre in Manchester, and at the Southampton Boat Show. To supplement the display work, several brochures were issued describing various aspects of the work or services of the Meteorological Office. Titles of those available on request include 'Offshore weather services', 'Sail weather wise' and 'Ship routeing'. One of the most popular has been 'Your holiday weather' which provides maps of the weather at major holiday resorts for each month of the year.

Keen public interest continued to be shown in the work and facilities of the Office. Many parties of visitors were received at the Headquarters in Bracknell and at the outstations where they saw operational work in progress. Members of the staff, acting in a voluntary capacity in their own time, gave a large number of talks to cadet associations, Women's Institutes, Rotary Clubs and other non-professional bodies. Replies were sent to a steady stream of letters received from members of the public of all ages and levels of technical understanding.

Services for the general public (overseas)

Meteorological offices serving the Royal Air Force stations in Malta and Gibraltar continued to provide forecasts for the general public by means of the Press, radio and television, and to cater for the needs of local government departments, oil-drilling operators, engineering and commercial concerns. During the year the Cyprus Government Meteorological Service took over full responsibility for public services in Cyprus.

Services for marine activities

The Meteorological Office continued to develop its services for the still-growing offshore oil and gas industry. A major part of the effort was provided

by the team of experienced forecasters at the London Weather Centre which specializes in offshore wind, wave and weather forecasting. This work is supported from the Central Forecasting Office by a variety of products based upon the output of the COSMOS computer system. Some of these have been designed especially for the Weather Centre's offshore work. A recent example includes the detailed predictions of surface wind made for a close network of points over the European continental shelf, using the fine-mesh numerical forecasting model. These are available at 6-hour intervals for periods up to 36 hours and have led to improvements in the quality of forecasts of wind and waves supplied to the offshore industry. A comprehensive review of the support given by the Meteorological Office for offshore operations appeared as the Directorate of Services Special Topic in the *Annual Report* 1976.

In 1977 Meteorological Office personnel were deployed offshore for the first time, on tugs and barges, in close support of particularly weather-sensitive operations. In May, one forecaster was placed on the lead tug engaged in towing out a steel and concrete structure some 150 metres high and 90 metres wide from the Moray Firth to the Heather Field. Other forecasters served on the derrick barges engaged in positioning this structure on site and in subsequent construction work. Later in the year forecasters were located at the platform construction yard at Loch Kishorn to be available for on-the-spot consultations by oil and construction company staffs during particularly difficult phases of the building and flotation of a giant concrete structure due to be towed out in 1978.

An increasing amount of work for the Office has been generated by oil-tanker operations inshore. The London Weather Centre regularly provides services for tanker-lightening operations around our shores when oil is transferred from large to smaller oil-tankers or vice versa. Tanker operations at the new oil terminals at Flotta in Orkney and at Sullom Voe in Shetland are expected increasingly to require close meteorological support. Discussions were held during the year to determine the requirements of the local authorities and of the oil companies concerned to ensure that appropriate meteorological advice is available when needed in critical situations.

The Principal Meteorological Officer of the London Weather Centre plays a key role in maintaining the necessary liaison with the offshore industry at various levels. He is assisted in this by a Meteorological Office consultant located in the Offshore Supplies Office in Aberdeen. The Principal Meteorological Officer, London Weather Centre, serves as a member of the Oceanographic Committee of the United Kingdom Offshore Operators Association. He represents the Office at annual meetings of the Meteorological Panel for the North Sea and adjoining waters and at quarterly meetings of the International Exploration and Production Forum. The former provides for the co-ordination of the work of the national meteorological services of countries having offshore interests on the continental shelf, while the latter is concerned with international co-operation within the offshore industry itself. The above-mentioned bodies cover wide fields of activities for which the advice of several specialized branches of the Meteorological Office are needed. However, the number of other committees and groups external to the Meteorological Office and concerned with one aspect or another of offshore work has grown to such an extent that formal co-ordination of the contributions of the various branches of the Office has become necessary. This is effected through an internal com-

mittee under the rotating chairmanship of the Heads of branches primarily concerned.

The general services to shipping via BBC Radio 2 and the Post Office coastal radio stations continued on the lines of previous years. The inshore waters forecasts were provided on Radio 3 and Radio 4 as in the past. They have been supplemented by others from the growing number of BBC local radio stations which, during the sailing season, transmit forecasts designed for the local inshore sailors. Southampton Weather Centre prepared special forecasts for the Royal Ocean Racing Club during the Admiral's Cup races and was consulted by several of the national teams. Many yachtsmen have used the automatic telephone weather service from Southampton which gives forecasts for inshore waters along sections of the south coast. Plans to extend this service for yachtsmen to other areas are currently under discussion with the Post Office. Yachtsmen who hitherto have found it difficult to take down in writing the BBC shipping bulletins and inshore waters forecasts can now record them by using relatively inexpensive cassette recorders. This has possibly contributed to a marked increase this year in the sale of the Meteorological Office Weather Plotting Chart for Yachtsmen. The chart enables the user to interpret the sea-area forecasts so as to build up a clearer picture of the broad weather situation.

A ship routeing service is provided to advise on North Atlantic and North Pacific passages and to offer advice in regard to the movement of tows. The object of the service for conventional vessels is to select the best route for a ship to follow in order to reach its destination in the shortest time with the least damage to hull and cargo, and with the most economical fuel consumption. The vessel's response to various wave fields is determined by extracting data from the deck log-books and constructing a ship/wave performance curve. The Ship Routeing section has now amassed a considerable amount of ship-performance information for various types of vessel and it is now possible to construct a wave/speed curve from basic data on ship size and type without recourse to the deck log-books. Wind and sea wave predictions at intervals of 12 hours for up to 72 hours ahead are supplied to the ship routeing officers by forecasters of the Central Forecasting Office and this information is used in conjunction with the performance curve to determine the most favourable course for the vessel to follow. Subjective consideration is given also to the loading state of the ship, to surface currents, and to navigational hazards such as shoals, ice and areas of fog. Communication with the vessel is usually by telex prior to sailing and via predetermined coastal radio stations when the ship is on passage. The provision of routeing advice to tows which do not have too restrictive weather parameters is similar to that for conventional ships but allowance has to be made for the slower speed of the tow and for their reduced manœuvrability. For tows with limiting weather factors, which may be wave height or period, amount of heel or wind force, the routeing service advises when and where to seek shelter and when to resume passage. During the year there has been an increase of 25 per cent in revenue from ship routeing activities.

The Central Forecasting Office (CFO) supplies guidance forecasts and warnings to forecasters on board the Trawler Support Ship stationed in the waters around the coasts of Greenland during the winter months from late November until the end of April. The forecaster on the support ship maintains close liaison with the British fishing fleets in the area, issuing local forecasts and warnings of gales, storms and ice accretion. During periods when there was no

forecaster aboard the forecasts and warnings were sent direct to the fishing fleet from CFO.

Oil slicks and pollution at sea are emergencies in which CFO plays its part in issuing forecasts and guidance advice. Warnings of hurricanes, cyclones and typhoons are issued to Lloyds when appropriate.

CFO works closely with the officers of the Storm Tide Warning Service who are responsible for issuing alerts on occasions when unusually high tides caused by strong winds give rise to the risk of flooding on the east coast of England.

The Main Meteorological Office at Pitreavie continues a forecasting service for North Sea fishing vessels during the season which lasts from October until March. Forecasts for some Royal Navy ships were supplied by Pitreavie and Plymouth Main Meteorological Offices. Plymouth also provided forecasts to the race controllers during the Admiral's Cup Fastnet Race. The number of enquiries for weather information in connection with yachting and other marine sports remained at a high level.

Special sea-area forecasts were issued from our office in Gibraltar for a short period in May and September for yacht races, that in September being for the Whitbread Round-the-world Race. The Main Meteorological Office at Luqa, Malta, continued a forecasting service (which commenced in October 1976) for the towing of two floating fuelling terminals on passage from Malta Dockyards to near Tripoli (Libya) and for the installation stage of the operation. The same office is also a participant in the Regional Oil Combating Centre's Contingency Plan for Malta which has recently been extended to cover the accidental pollution of the sea by oil. This office also provides sea-area forecasts and gale warnings for Maltese trawlers over an area about 200 miles radius from Malta.

Services for civil aviation

Meteorological services for civil aviation in the United Kingdom are provided by the Meteorological Office as agent of the Civil Aviation Authority. The Office has a dual role in relation to the Authority, first to give technical advice on meteorological matters and second to provide the staff and technical facilities to meet the Authority's requirements and standards.

Civil Aviation Forecasters within the Central Forecasting Office (CFO) at Bracknell are responsible for the forecasts of upper winds and temperatures required by civil aviation. They use data and forecasts processed by the Meteorological Office computer. These forecasts, together with forecasts of significant weather prepared at London/Heathrow Airport, form the basis of flight documentation distributed to major airports throughout the United Kingdom and Europe. Distribution within the United Kingdom is by the civil aviation facsimile network (CAMFAX), the hub of which is in the meteorological office at Heathrow. Charts of forecast upper winds and temperatures for levels from 5000 to 40 000 ft ($\approx$ 1500 to 12 000 m), significant weather and tropopause height are broadcast by CAMFAX every six hours to cover flights to destinations in Europe, the Mediterranean area, Canada, USA and the Caribbean region. Meteorologists at airports add information concerning take-off and landing conditions to complete the flight documents which are presented to aircraft captains at pre-flight briefings.

The Principal Forecasting Office at Heathrow is designated the European Area Forecast Centre for all flights to the USA, Canada and parts of the

Caribbean from departure airfields in Europe. Flight documentation for these flights is passed by land-line facsimile to Dublin, Paris, Frankfurt, Rome, De Bilt and Copenhagen and by radio-facsimile to more distant recipients. Routine half-hourly observations of weather are made at all major airports in the United Kingdom as part of the network of airport weather reports continuously exchanged between airports throughout Europe and the Mediterranean area over discrete civil aviation teleprinter circuits. Information on the weather expected at flight destinations is also exchanged world-wide for the benefit of aircraft captains and flight planners.

Meteorological services for general aviation (private flying, air taxi services etc.) are provided on request by local civil and RAF meteorological offices. This type of service is specialized and calls for detailed assessment of cloud, visibility, low-level winds and weather hazardous to light aircraft. The general aviation visual flight service provides recorded forecasts of flight conditions in each of a number of defined subdivisions of England and Wales. Each subdivision is given a coding which indicates whether flight under visual flight rules is appropriate. The forecasts are available to the users by dialling published telephone numbers.

Helicopter operations in support of the offshore industry have continued to increase during the year. The operations require a specialized service in which particular attention is paid to low-level phenomena including visibility, low cloud and icing, and the speed, direction and gustiness of the wind. The forecasting services for helicopters operating to North Sea rigs and platforms are centred upon the Main Meteorological Offices at Honington, which caters for the southern North Sea, and Prestwick which, together with its subsidiary offices, has borne the brunt of the work generated by the fast-growing northern oil and gas fields.

To serve air operations in the Shetland area a new meteorological office is under construction at Sumburgh Airport. Pending its completion, Meteorological Office staff commenced observing duties in July 1977, using Air Traffic Control accommodation. Forecasting is expected to begin locally in spring 1978.

For reasons of economy the Civil Aviation Authority withdrew its requirement for a meteorological office at Liverpool Airport. Responsibilities for provision of flight and local forecasts for the airport were transferred in May 1977 to the meteorological office at Manchester Airport. The local issue of flight documentation and weather observing at Liverpool were undertaken by Civil Aviation Authority staff from August and September.

Relocation of the Main Meteorological Office at Preston has become necessary with the transfer of Air Traffic Control functions from Barton Hall, Preston, to Manchester Airport. Its long-planned amalgamation with the Manchester Airport meteorological office is expected to take place early in 1978. Redesign of the present Manchester accommodation was completed and major structural alterations were made in the latter part of the year. The local Meteorological Office staff showed considerable fortitude in maintaining services of high professional quality under very trying conditions while the rebuilding was under way.

Forecasts for Air France and British Airways scheduled supersonic flights by Concorde aircraft to New York, Washington and Bahrain have been provided from CFO and Heathrow. They contain information on winds and temperatures at levels up to 55 000 ft ($\approx$ 17 000 m), together with forecast significant

weather conditions, such as hail, clear-air turbulence and convection cloud tops, at levels above 25 000 ft ($\approx$ 8000 m). The latter are particularly hazardous for aircraft in supersonic or transonic flight. Concorde's operations are especially sensitive to the temperatures experienced on take-off and also during supersonic cruise. The Meteorological Office has continued to co-operate closely with British Airways in developing forecasting procedures which enable the aircraft's capacity to be fully utilized.

The supply of wind and temperature data to British Airways for flight-planning purposes is entirely automated. Such data, referring to about 35 000 ft ($\approx$ 11 000 m), are computed in the Meteorological Office computer system (COSMOS) in the course of the routine numerical forecasting runs. The data are then transmitted in grid-point format over a special link for direct input to the machine used by the airline for the computerized preparation of flight plans. Similar data are supplied to Shanwick Oceanic Control at Prestwick.

During the year the British Civil Aviation Standing Conference set up a group to review the requirements for meteorological services in this country in support of civil air operations. Senior members of the Office attended, by invitation, two meetings of the group which were held at the Headquarters of the Civil Aviation Authority.

In June the Meteorological Services for International General Aviation Group (METSIGAG) met in Paris. It is a working group of the International Civil Aviation Organization. A representative of the Meteorological Office attended as a member of a United Kingdom delegation. The meeting reviewed the support required for general aviation flights across national boundaries and the formats in which exchange of information should take place between national meteorological services.

The year saw the end of the award scheme under which awards have been made annually to captains and navigation officers who have shown particular interest and zeal over a long period in the making of weather reports whilst in flight or soon after landing. The scheme began in 1954 with the co-operation of the Guild of Airline Pilots and Navigators and of leading British airlines. The premier awards have taken the form of brief-cases inscribed in gold with the award winner's initials, two being given each year. In addition, a number of awards of books to the recipients' choice were also made. The main presentations have taken place annually at ceremonies at which the Director-General has presided and which have been publicized in the various journals of the industry. Over the years the scheme has done a great deal to encourage regular air reporting, especially over the oceanic areas where other upper-air data are notably sparse. It was decided to terminate the scheme this year for two main reasons. First, and to the regret of many of those concerned, but due to automation and for economic reasons, the process of forecasting for civil aviation is becoming increasingly centralized. The meteorologist and the civil air pilots and navigators who have enjoyed face-to-face discussions at briefings over many years are becoming separated. Secondly, on the North Atlantic routes of particular interest in this country, air reports are no longer made by the aircrews as a matter of choice but by designation of selected aircraft by the relevant Air Traffic Control Centre. As a result all aircrews now play an equal part and the award system has become inappropriate. The final ceremony took place at the Meteorological Office College, Shinfield Park, in October when Captain D. H. Mackie, formerly of British Airways, and Navigation Officer

L. C. Williams, formerly of British Caledonian Airways, were each presented with a brief-case.

Services for civil aviation (overseas)

Services for civil and general aviation were provided from the offices at Royal Air Force stations in Malta and Gibraltar in the Mediterranean and at Wildenrath and Gütersloh in Germany. All commitments to civil aviation in Cyprus, other than at RAF Akrotiri, formally ceased on 3 January 1977 when the Cyprus Government Meteorological Service took over that responsibility. The provision of services to civil aviation at Maşīrah and Şalālah was undertaken by the Oman authorities with the withdrawal of UK staff from both locations on 31 March 1977.

Services for military aviation

Senior officers of the Meteorological Office are located at Headquarters Strike Command and at Headquarters Royal Air Force Germany. These officers act as advisers on meteorological matters to their Air Officers Commanding-in-Chief and they are responsible for the organization of meteorological services to meet the needs of Strike Command and the Royal Air Force in Germany.

The forecasting services for the Royal Air Force at home continue to be provided by offices which are grouped largely in conformity with the RAF organization. A Principal Forecasting Office at Headquarters Strike Command and Main Meteorological Offices at various centres, functioning 24 hours a day, control and advise subsidiary forecasting offices located on airfields, enabling them to meet the requirements of military aircraft operating in widely differing roles. At subsidiary forecasting offices a forecaster is on duty at times which depend on the stated requirements of the Royal Air Force. Many of these offices also provide services for civil aviation and for the general public.

The only changes in the organization in the United Kingdom during the year were the closure, at the end of June, of the subsidiary forecasting office at the MOD(PE) station at Pershore—the last of the closures resulting from the 1975 Defence Review—and the withdrawal of the subsidiary forecasting office from RAF Fairford. Subsidiary forecasting offices continue to meet the needs of the MOD(PE) aviation stations at Bedford, Farnborough and Boscombe Down and the Army Air Corps stations at Middle Wallop and Netheravon.

The powerful computer system at Bracknell provides major support to the offices serving military aviation and plans are being prepared to extend this support to the provision of flight forecast documentation. However, the personal briefing of aircrew and of personnel concerned in operational planning is considered by the RAF and Army Air Corps to be an essential service into the foreseeable future.

In the meantime, the Principal Forecasting Office at Headquarters Strike Command and the Main Meteorological Office at Headquarters No. 38 Group continue to prepare a comprehensive six-hourly program of area and route forecasts in chart form which is issued by facsimile to subsidiary forecasting offices to meet most operational requirements. These routine issues include forecast charts of the surface-pressure distribution and significant weather in addition to forecasts of winds and temperatures for standard upper levels.

The routine issues are in a format suitable for self-briefing and are copied at subsidiary forecasting offices for issue as flight forecast documentation to aircrew.

Mobile meteorological units continue to support certain Royal Air Force and Army elements in the field and they have participated in exercises in the United Kingdom and overseas. Each unit has its own air-transportable sets of instrumental and communication equipment for use at locations away from permanent meteorological offices. The sets include radio-teleprinters, radio-facsimile recorders and equipment for receiving weather satellite information. Forecasters in the mobile units hold commissions in Class CC of the Royal Air Force Reserve of Officers. A mobile meteorological unit formed part of the static display at RAF Finningley on the occasion of Her Majesty's Silver Jubilee Review of the Royal Air Force.

Offices were opened temporarily for short periods at certain locations to provide services during large-scale exercises and special operations. A forecaster was again detached to Barksdale, Louisiana, to provide support to the RAF team participating in the United States Air Force Bombing and Navigation Competition.

The provision of services for the Royal Air Force in Germany continues unchanged. A Main Meteorological Office at the Joint RAF/Army Headquarters at Rheindahlen supports subsidiary forecasting offices at the four airfields of RAF Germany and at the Army Aviation Corps airfield at Detmold.

United Kingdom defence requirements in the Mediterranean are met by Main Meteorological Offices in Cyprus, Malta and Gibraltar, with radiosonde stations also located at the latter two offices. The facilities in Cyprus suffered a tragic blow in December 1977 when an aircraft of the United States Air Force crashed on take-off at RAF Akrotiri, completely destroying the main meteorological office and its communication centre. However, a temporary office was quickly established and services, including flight documentation, were restored within 24 hours of the accident. Arrangements for a more permanent replacement meteorological office are well advanced. In addition to the pilot of the US aircraft, two Cypriot meteorological assistants, a radio operator and the office cleaner died in the accident. The duty forecaster, a Senior Scientific Officer, was severely burned and died of his injuries 36 hours later. Two other Cypriot radio operators received serious burns and one was later transferred to the Princess Mary's Hospital at RAF Halton.

The observing office at Ayios Nikolaos was closed in October as part of the rationalization of facilities in Cyprus and, following the withdrawal of the RAF from Maşīrah and Şalālah in March 1977, the meteorological offices at both locations were handed over to the Oman Government as fully equipped observing offices. There are now no Meteorological Office stations east of Cyprus.

The voice-broadcast from West Drayton of plain-language reports from major RAF aerodromes (VOLMET) was continued. This broadcast is provided mainly to meet the needs of RAF transport aircraft returning from overseas to bases in the United Kingdom. Consideration is being given to the possible automation of the supply of data for this broadcast.

The Office continued to meet the requirements of the Royal Air Force for meteorological training by the provision of lectures where necessary, although the emphasis is moving towards tutorial assistance, rather than lecturing, as a result of the growth of programmed learning methods.

Other services for the Army and Establishments of the Procurement Executive, Ministry of Defence

Offices are maintained at the Royal School of Artillery, Larkhill, at the Royal Aircraft Establishment (RAE), Aberporth, and at the Proof and Experimental Establishments (PEE) at Shoeburyness, Eskmeals and Pendine. The office at Larkhill also provides meteorological support for RAE and PEE units located within the Salisbury Plain area. The office at Shoeburyness also supports the Atomic Weapons Research Establishment at Foulness. The replacement of the radiosonde equipment by the Mk 3 system is taking place at Aberporth, Shoeburyness, Eskmeals and Larkhill.

Meteorological Office staff were attached to the Army practice camps at Sennybridge and Otterburn for several periods during the year to provide meteorological information for ballistic purposes and to the Hebrides Rocket Range for a program of missile firing during May and June.

An experiment to investigate the effect of the natural variability of wind on tank gun-fire continued, and information was provided for a number of projects connected with the development of weapons and military equipment.

Liaison with the Navy Department

Close co-operation is maintained with the Director of Naval Oceanography and Meteorology to ensure the co-ordination of plans to meet the requirements of all three Services at home and overseas.

International defence services

The Meteorological Office continues to participate actively, on behalf of the United Kingdom, in the work of NATO and CENTO committees concerned with the international co-ordination of meteorological support for military needs, and contributes to studies associated with that support. The chairmanship of the Meteorological Group of the NATO Military Committee was taken up by the United Kingdom during the year. The Office took part in the major NATO-wide exercise WINTEX 77 in March and provided support to other NATO exercises.

Services to the Home Office

The meteorological requirements of the UK Warning and Monitoring Organization (UKWMO) of the Home Office have been kept under review. Detailed plans for meeting, as effectively as possible, the requirements of UKWMO continue to be developed and practised in regular national and international exercises in which Meteorological Office staff take part. Lectures have been given to groups of Home Office Sector Scientists, Chief Warning Officers, and members of the Royal Observer Corps who are equipped and trained to make observations at ROC posts in times of emergency.

Services for nuclear establishments

Arrangements for Main Meteorological Offices to supply information to nuclear establishments of the United Kingdom Atomic Energy Authority and the Electricity Generating Boards in the event of accidental release of radioactive or toxic material were extensively reviewed and exercised. Similar arrangements cover emergencies which may arise from nuclear submarines in port or from radioactive material in transit over land.

Climatological Services

For climatological work a much closer network of observing stations is needed than for forecasting purposes. Most of the synoptic reporting stations also provide climatological information, about half of them contributing hourly data; but no less than 80 per cent of the observing stations in the United Kingdom climatological network (see Table IV on page 65) are maintained by public bodies and private individuals who are prepared to make regular daily readings and send them to the Office. Clearly those involved have an interest in the weather, but this is nevertheless a voluntary service of a high order for which the Office is most grateful. By association over remarkably long periods many of our co-operating observers become valued friends, and in 1977 it was a pleasure to present suitably inscribed barographs as a token of appreciation to three observers who, between them, had served the Office for a total of 120 years. The cost of maintaining a station has risen sharply in recent years and, although the network will remain essentially voluntary in character, a greater measure of support will be needed over the years ahead; during 1977 financial provision was made for this, so the future of the network can now be viewed with increasing confidence. There are still some serious gaps, particularly in the less-populated upland areas, but development of automatic equipment is continuing and this will undoubtedly strengthen the network in the 1980s.

The returns from the climatological stations produce each month about 6 million bits of information, so it is not surprising that automatic data-processing methods now play a dominant role in the provision of climatological services. The vital first step is to convert the manuscript data into machinable form and this is achieved by processor-controlled keying (PCK) in the Data Processing Branch at Bracknell. Using the computer, thorough and consistent quality-control checks are then applied to the data and, for each failure, the computer generates a query message for resolution by human scrutiny, and reference back to the observer when necessary. Amendments to the data sets have hitherto been made by means of appropriate instructions keyed to tape in the PCK section and subsequently processed by the computer. During 1977 an allocation of disc-storage space on-line has made it possible to examine some of the data more thoroughly by using a visual display unit (VDU) located in the Climatological Services Branch. By using the terminal keyboard attached to the VDU, corrections may then be made directly without involving the PCK section, and it is hoped eventually to make all data-set amendments in this way. After completion and cross-checking of all the quality-control processes, the amended data sets are accepted into the magnetic-tape archive of climatological data which thus grows steadily and is kept up to date.

As opportunity offers, the machinable archives are also expanded, both backwards in time and in station coverage. An easing of the staff shortage in the PCK section during the year has made possible some useful additions to the United Kingdom data sets, and the considerable backlog of unkeyed data from overseas stations has largely been eliminated. For convenience of access, archive data are filed both in single-station sets covering many years and in yearly sets which include data from many stations. Single-station sets of hourly and daily data are now available and some of these have been extended back to pre-war days; yearly sets, including all available data, have been assembled for the years from 1968 onwards. Another major project completed during 1977 has been the

compilation of a computer file which lists site details of all the climatological stations; this is available on-line for quick reference and can be kept up to date by using the VDU. The machinable archive is thus now quite extensive and can be accessed for research and investigations, also to answer enquiries and to produce tabulated data for publication. The considerable investment of staff time needed to compile the archive is bringing increasing dividends, and complex analyses that could not possibly have been carried out by manual methods are now undertaken on a commercial basis.

Preparation of the *Monthly Weather Report* has continued throughout the year and some small changes have been made to improve the appearance of the tables; minor problems have unfortunately continued to affect all stages of production and it has not yet been possible to reduce the six-month delay in publication. The material for Part I (North America) of *Tables of temperature, relative humidity, precipitation and sunshine for the world* is now virtually complete and it is hoped that this will be published late in 1978; work has commenced on Part IV (Africa). The *Snow Survey of Great Britain* 1976/77 has been published, and also *Climatological Memoranda* on dry-bulb and wet-bulb temperatures at many locations, both in the United Kingdom and overseas. For many years it has not been possible to publish upper-air data but a new style of presentation, which can be obtained by computer processing, has now been agreed. Work is well advanced and volumes covering the years 1961–70 should be published in 1978; data for the decade 1951–60 will be published subsequently. A start has also been made on the revision and updating of *Tables of surface wind speed and direction over the United Kingdom.*

Despite a year without the marked climatic extremes of 1976, the number of climatological enquiries dealt with at Bracknell, Edinburgh and Belfast continues to increase (see Table XIII on page 69); as in previous years, the construction industry produced the largest proportion of enquiries. An unusually large number of requests came from building contractors who were involved in claims following the delay to work by inclement weather, particularly during the 10-month period from September 1976 to June 1977 which was the wettest such period over England and Wales for 100 years. Whether or not particular weather is deemed inclement is naturally a matter for the industry rather than the meteorologist. However, in an attempt to simplify and standardize our response to enquiries of this type, the matter was discussed with a legal expert from the National Federation of Building Trades Employers; unfortunately, because of the variety and complexity of legal contracts, a unified approach has not yet been found. There has also been a continuing dialogue with the Chief Planning Engineer of a major firm of contractors in an attempt to optimize the climatological input needed at the tendering stage of contracts for public works; joint findings will be presented at the next Royal Meteorological Society course for graduate civil engineers. The major requirements at the design stage of building work continue to be for information on extreme wind, in connection with wind-loading calculations and glass specifications, and on temperature and humidity, needed for the planning of heating, ventilating and air-conditioning installations.

Many of the enquiries from civil engineers and architects relate to the design and planning of new buildings and public works in overseas areas, particularly in the oil-producing countries of the Middle East and Africa. Design wind information is often needed and a special effort has been made to collect and

analyse all the basic wind information available from the developing countries. Enquiries of particular interest during the year included requests for estimated extreme wind speeds at the proposed sites of television relay masts on the summits of Mount Olympus and other peaks and ridges in Cyprus, and for frequencies of intense falls of rain in connection with storm drainage and flash flooding at Ar Riyān in Yemen (People's Democratic Republic).

The advice of the Climatological Services Branch is also regularly sought on legal and insurance matters, mostly in connection with road accidents or with damage to property and to goods in transit; many Certified Statements have been issued for civil cases, Witness Statements are made to the police for criminal cases, and evidence is given in courts of law when necessary. The supply of degree-day information to the Department of Energy, for distribution to industry as an aid to national fuel economy, has proved to be a very popular service; during 1977 a similar scheme, using a higher base temperature, was introduced for the Department of Health and Social Security for the monitoring of heating costs at hospitals in all parts of the country. The applications of climatological services are many and varied: during the year information or advice was given in connection with storage conditions for old parish registers in damp country churches, cross-wind effects on the Advanced Passenger Train, wind-power generation over shallow inshore waters, solar heating equipment, condensation in roofs of buildings, diesel-smoke tests for heavy goods vehicles, gaseous pollution in a motorway tunnel and noise levels of motorway traffic. A major computer analysis to determine variations of wind chill, degree days, temperature and rain at a large number of stations has been undertaken for the Water Research Centre as part of a study of cardiac ailments.

The land climatologist has been involved with several of the enquiries mentioned above. He acts both in an advisory capacity within the Office and as adviser to outside bodies; for example, he recently undertook studies, in conjunction with the Building Research Establishment and other interested parties, to develop optimum methods of analysis and presentation of climatological data for use by heating and ventilating engineers. He continues to serve on various committees of the British Standards Institution, including a new one set up during 1977 to produce a Code of Practice which brings together those parts of existing Standards dealing with the effects of climate on the design, construction and operation of buildings and structures. In May he attended a working group meeting of the International Organization for Standardization, held in Paris, to discuss the European Code of Practice on Wind Loading. Applied research work is also carried out as time permits and, in view of the great importance of design wind-speed calculations for structural safety, he has started to revise the *Climatological Memorandum* on extreme winds over the United Kingdom in the light of recent advances in methods of extreme-value analysis and using the much more extensive anemograph data sets now available.

Applied research of a different kind has been a major concern of the Building Climatology section during 1977. Improved maps for the entire United Kingdom have been prepared to indicate annual average amounts of driving rain on walls facing in any of twelve different directions. This simple approach was refined by taking into account both the reduction of unobstructed wind speed within a suburban environment and the amount of rain that actually

impinges on a wall (i.e. the collection efficiency of the building). An assessment was then made of the likelihood of rain penetrating through a wall; this led to consideration of the probable frequency of spells of driving rain and of the moisture-holding properties of different types of brick. A report on all this work has been sent to the Building Research Station as a basis for more effective Codes of Practice, for example that concerning cavity fill in house walls.

The Climatological Research group in the Branch carries out research of a more fundamental nature. A study of the interpolation accuracies attainable in temperature and sunshine networks over uniform terrain was completed and published; the results indicate the inter-station spacing necessary to achieve given accuracies of interpolation and, for the first time, provide some quantitative guidance for network planning. This work will eventually be extended both to other elements and to areas of more complex topography. Characteristic patterns of spatial variation of climatic elements may be defined by factor analysis, and stations can be grouped by using cluster techniques. With the aid of a close rectangular grid it is then possible to classify the whole country by objective methods. This investigation should give guidance on optimum areas for quality control, assessment of the representativeness of each station, and selection of the most appropriate station to use as a basis for answering climatological enquiries. Other work carried out by the group during the year has included a detailed study of the hot spell from 23 June to 8 July 1976, and an investigation to determine optimum averaging periods for use when giving advice on the most probable values of certain climatic elements over future periods.

The office in Edinburgh provides a focal point for climatological work in Scotland. The establishment and maintenance of adequate networks of observing stations is a particular concern in a country of such varied terrain, and automatic instrumentation is necessary to give coverage in remote areas. The need for more detailed rainfall information is acute and the installation of magnetic-tape event recorders (MTER) has gone ahead; 19 are now operational, but there are continuing problems due to the variable effects of snow and freezing temperatures on the tipping-bucket mechanism. Because of a combination of hardware faults and lack of experience in instrument handling, data retrieval rates are not yet entirely satisfactory. For this and many other reasons there is a need to provide training for co-operating observers, few of whom are able to afford the time to travel to the Meteorological Office College for a one-week course. It has therefore been decided to mount a series of two-day courses in Edinburgh during 1978, and initial response to the forward publicity is very encouraging.

The winter of 1976/77 in Scotland was colder than in recent years and it is clear that the previous run of six mild winters resulted in a relaxation of normal precautionary measures in the building industry; in consequence there were many cases of frost damage, followed by requests to the Edinburgh office for information. Another factor contributing to the marked increase in enquiries during the year was the introduction by the Scottish Certificate of Education Examining Board of a new syllabus for Higher Grade Geography which includes project work on past incidence of severe weather. After discussion with the nine Regional Education Authorities, it was agreed that standard descriptions of past weather events would be prepared for supply to children on request, in return for fixed annual payments by each Authority.

It is noted with appreciation that, despite a continuing background of unrest in the province, the Senior Meteorological Officer and his staff at the Belfast office have once again maintained full climatological services. Under the agreement to provide reciprocal services, co-operation with the Northern Ireland Departments of the Environment, Agriculture and Finance continues to be both close and effective. Cordial relationships also exist with the Meteorological Service of the Republic of Ireland, and these have been of particular benefit in connection with rainfall matters during 1977. The demand for climatological services in Northern Ireland is still increasing, notably from builders and contractors, and also from legal and insurance interests concerning claims arising from contract delays due to inclement weather. Enquiries related to fuel economy have also risen sharply.

Operational and climatological work on sea-ice have continued throughout the year. In addition to the routine production of daily charts covering the North Atlantic for dissemination by radio-facsimile broadcast, and of monthly charts for the northern hemisphere which are published for climatological and research purposes, advice on sea-ice matters is given as necessary; thus, during the year, the leaders of the Joint Services Expedition to east Greenland, and also the crew of the leather-covered boat *St Brendan* which was to sail from Iceland to Newfoundland, visited Bracknell for personal briefing on the ice problems they were likely to encounter. Work also continued on the sea-ice and ocean-current sections of the Admiralty *Pilots*, five volumes of which were revised during 1977.

However, the predominant activity of the Marine Climatology section of the Branch has been the answering of enquiries; these have continued in large numbers and many of the demands were both complex and urgent. The suite of programs designed to permit rapid response to the more usual requests has proved invaluable; further development of this approach has ensured that the service now offered is both of high quality and commercially competitive. The many components of off-shore industry activity over the seas surrounding the British Isles provide the major proportion of enquiries, but for a variety of purposes there is also a considerable demand for information world-wide. During 1977, services provided have included an evaluation of weather hazards such as high winds, freezing spray and sea-ice likely to affect the tow of a barge from Teesside to Tomsk by way of Nordkapp, the Kara Sea and the River Ob'; estimation of extreme wave heights in connection with construction projects near the coasts of Libya and Japan and in the Gulf of 'Aqaba; and assessment of the frequency of different ranges of visibility in the Red Sea and near the West Indies to assist with the design of lighthouses.

Although the computer programs are complete for the continuation of *Marine climatological summaries for the Atlantic Ocean*, produced on behalf of the World Meteorological Organization (WMO), the necessary data sets are still not available and no further volumes have been published. WMO has now decided that data on sea-surface currents should also be exchanged internationally and, as a leading authority on computer-processing of such data, the United Kingdom was asked to set up a world centre for this work. It has been agreed that the marine section of the Branch will in future collect, quality-control and archive observations on currents made by ships of all nations on all oceans of the world; no decision has yet been taken about publication.

The marine climatologist provides advice in connection with many activities

at sea and, continuing the trend established last year, has been very much involved in matters concerning the offshore industry. He has been consulted many times by the Oceanographic Management Committee of the United Kingdom Offshore Operators Association (UKOOA), and has recently undertaken a major contract to review the data collected over three years on the UKOOA weather ship located east of Shetland, to recommend appropriate analysis and presentation methods, and to produce a summary report on the meteorological and oceanographic data. In November he attended a meeting in Geneva of the WMO Working Group on Marine Climatology at which final arrangements were made for the international exchange of data on sea-surface currents; he has also taken over responsibility for the United Kingdom input to the WMO Historical Sea Surface Temperature Data project, due for completion in 1978. His research work has been directed primarily to statistical matters and, in particular, to the problems of the representativeness of observations which, being obtained from ships of opportunity, are by their nature unevenly distributed both in space and in time; it is clearly of considerable importance to remove bias from the data sets on which advice is based.

Services for Hydrometeorology

The features and characteristics of rainfall over the United Kingdom have continued to be monitored through the collection and quality control of observations from a network of about 6500 rainfall stations, only some 10 per cent of which are equipped by the Office. These data have been preserved in a permanent archive at Bracknell which has overall responsibility for this work; as in previous years, the Edinburgh office administered and inspected stations in Scotland and the Belfast office carried out these functions in Northern Ireland.

By far the greatest number of rain-gauges in the national network are operated by the Regional Water Authorities in England and their equivalents in Wales, Scotland and Northern Ireland. Not surprisingly, at this time, there are pressures on the water authorities to cut costs and this is reflected in moves to reduce the rainfall data-gathering network. This has resulted in a joint study, with the Institute of Hydrology, of the methods that might be employed to arrive at acceptable rain-gauge spacings, given user views on the required accuracy of rainfall estimates at points between the gauges. This theoretical study has moved on to a study of the practical problems arising from the implementation of rationalization procedures over the Wessex Water Authority area. The outcome is expected to be a guide to recommended procedures for the rationalization of rain-gauge networks over other water authority areas.

The computer-produced index of rainfall stations in the United Kingdom, known as RAINMASTER, has been maintained during the year. The index lists site, equipment and details of length of record of some 14 000 present and past rainfall stations, and is the subject of close liaison between the Office, the various water authorities and the Institute of Hydrology. Copies of RAINMASTER, or extracts from it, are available to customers.

The computer-based procedures for the quality-control of the rainfall observations have been subject to continuous review. Whilst all the original observations are faithfully preserved, these inevitably contain errors, human and instrumental, random and systematic. The computer quality-control pro-

cedures attempt to remove and correct the more commonplace and obvious errors through comparison with the observations of neighbouring stations. The network is dense enough to make this a realistic approach. There remain observations which fall outside the limits for automatic acceptance and require the judgement of a human analyst and a wider synoptic view than that provided by data from neighbouring stations. This work is labour-intensive, but is an essential step for the establishment of a good data base. Amended data are always so indicated and the original information remains available. The experience of the human analysts will eventually be incorporated into more sophisticated quality-control procedures but one cannot foresee the complete displacement of men by machine in this respect.

The digitization of daily autographic rainfall charts presents different problems from those arising in the treatment of simple rainfall observations. The more detailed information contained in the autographic charts is an essential addition to our knowledge of rain-intensity profiles and finds application, for example, in the design and sizing of structures to contain or carry away excess surface water. The precision encoding and pattern recognition (PEPR) equipment at the Nuclear Physics Laboratory at Oxford University continues to be used to convert the information contained in autographic rainfall charts into quantitative information on magnetic tape, that is to a form which can be manipulated by computer and which is compatible with the end product of other rainfall observations; 100 000 further autographic charts were so processed during the year, the majority from the network of stations maintained by the Greater London Council. The network of direct magnetic-tape event recorders (MTER), which log the occurrence of successive rainfall accumulations of 0·2 mm in small tipping buckets, has been maintained. The number deployed to measure rainfall of short durations in remote areas, chiefly Scotland, has increased, as has the network deployed to study small-scale variations in space and time of rainfall over a catchment of the Gloucester Division of the Severn–Trent Water Authority. The latter study will lead to improved estimates of the representativeness and likely error of point rainfall observation.

Rainfall observations were presented as routine in the *Daily Weather Report* and *Monthly Weather Report*. The publication *British Rainfall* has been abandoned but alternative arrangements have been made for distribution of part of the information (the General Table) that was previously presented in that publication. These data, from 1968 onwards, will be available under a new title, *Monthly and Annual Rainfall of the British Isles*.

The number of hydrometeorological enquiries continued to show the marked upward trend of recent years and in 1977 reached 8900 which is 6 per cent more than those made in 1976. As in previous years, the enquiries were most frequently related to building, drainage, legal matters and the recent past. The basic rainfall information for such enquiries is held readily accessible in the computer. Within the short period of a normal telephone conversation the computer can be interrogated and data presented on a display screen for reading off to the telephone caller. If required, a printed copy of the data can be dispatched within 24 hours. Many building contractors, having satisfied themselves of the value of the data that can be supplied, have now placed standing orders for regular statements of daily rainfall totals over their spread of sites, together with estimates of the working hours lost due to rain. Others are

using specific weather information in their forward planning and contracts by calling for typical monthly averages of these figures. Since it would be unusual for us not to be able to find a rainfall station within a few kilometres of any proposed work site, realistic data can be provided.

The increase in enquiries concerning drainage work is again to be associated with the wider awareness of the facilities on offer, following the publication of the *Flood Studies Report* and Meteorological Office membership of committees charged with reviewing standards on drainage-design procedures.

The suite of computer programs held in the Meteorological Office enables tabulations to be made of rainfall amounts or intensities in specified durations (1 minute to 25 days) which will be equalled or exceeded for a whole range of return periods, from as often as twice a year to as seldom as once in 200 or 500 years. Storm profiles can also be provided which, for any catchment and return period, give intensities of rainfall at either side of the peak intensity. Such information is basic to the design of systems to carry away excess surface water safely.

Following enquiries on the 1975–76 drought, computer programs became available to arrive at the percentage of average rainfall corresponding to nominated return periods (from 2 to 500 years) for any number of consecutive months (1 to 120) starting in any named month. Tabulations can be made for a point or for a catchment. The customers for this type of information remain the water authorities in England and Wales, who have also sought other hydrometeorological information. A typical enquiry was concerned with the estimate of daily values of areal rainfall, actual evaporation, soil moisture deficit and hydrologically effective rainfall, for a 50-year period, for the catchment of the Ouse at Denver, Norfolk.

Work continued on the long-term contract for the provision to the Central Water Planning Unit of estimated monthly and daily rainfalls over a large number of catchment areas; in some cases, the estimates are required for periods well back into the 1800s. Contract work for the Water Data Unit and their Surface Water Survey, which calls for estimates of average areal rainfall, both monthly and annually, was extended to 400 new catchment areas, and back to 1955 in some instances. The number of areas for which current rainfall is now calculated month by month for that Unit was increased from 800 to 1000.

Not all enquiries come from water resource planners. Some enquiries came from those who see the presence or absence of rainfall as a hazard to their operations and need statistics which offer information on the frequency of certain risks. The Plant Protection Service of ICI was supplied with daily estimates of rainfall and soil moisture deficit in connection with the effectiveness of sprays against potato disease; the South Eastern Gas Board saw the need for soil moisture deficit information as an input to their studies of gas-main fractures; the Home Office Fire Department required information on soil-moisture availability, since this is seen as a major element in forest and heathland fires.

Work, on repayment, was undertaken for consulting engineers and included work for sites outside the UK. Estimates were provided, for example, on the evaporation from sewage stabilization lagoons in Saudi Arabia and on the rainfall regime in parts of Brazil. Arrangements were concluded for the 3-month secondment of a staff member to a consultancy group for field work in South Korea.

Bulletins of *Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain* were issued at frequent intervals during the year. At the same time, basic scientific work was undertaken to improve the physical basis of the calculations, and a trial was conducted of the more informative bulletins that will be available for the 1978 season. These bulletins are seen as natural candidates for inclusion in the service to be offered by the Post Office Viewdata system (see page 12). There will also be possibilities for improvement in day-to-day water management for those concerned with the effectiveness of rainfall for stream flow and aquifer recharge.

The procedures involved in the measurement of the intensity and amount of rainfall by radar have been discussed in previous *Annual Reports*. Over the next few years operational radars will be established for this purpose. The methods and procedures whereby the data so obtained can be integrated with those provided by traditional rain-gauge networks have yet to be developed and tested. Work has commenced in this area.

The completion of large-scale data collection by the Meteorological Office team attached to the Institute of Hydrology ended the experimental phase of the hydrometeorological study of the forest environment at Thetford. In 1977 the data, including detailed short-term measurements of wind speed, temperature, humidity and carbon dioxide, together with appropriate biological data, passed through quality-control procedures. The analysis will lead to a model describing the biological control of the evaporation from a forest. The study of the rainfall interception loss from forest stands was also completed and results are in the process of publication. Since many water-catchment areas are forested (not least because of the need for optimum land use and for erosion control), there are very practical applications underlying these fundamental studies. Co-operation on hydrological matters continued at international and national levels through the World Meteorological Organization and the UK National Committee for International Hydrology.

Services for Agriculture

Most of the Meteorological Office staff employed specifically to provide assistance to the agricultural community are located at regional centres of the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food (MAFF) at Bristol, Cambridge, Harrogate and Reading, whilst a further team located at Edinburgh acts with and through the Colleges of Agriculture in Scotland (who provide agricultural advice in that country). These posts are provided on a repayment basis. The provision of meteorological support for the ADAS centre at Reading in 1977, together with a strengthening of the teams at Cambridge and Harrogate, even in these times of financial restraint, are measures of the value and importance which MAFF attaches to meteorological help and advice; these include collaboration on weather-sensitive agricultural problems, through the interpretation and evaluation of meteorological data, and also the application of the principles of environmental physics, where a restatement of the farming problem in terms of the concepts of other disciplines is helpful in moving ahead. Examples here are the role of heat and moisture budgeting in animal production and housing, and in the production, protection and storage of crops.

In addition to their advisory function, staff at the outstations continued with

investigations having longer-term significance; an attempt is made to provide a specialist within the Meteorological Office for each part of the spectrum of farming problems that reach us. For example, work has been done in 1977 on interactions between weather and insect pests such as the pygmy beetle (which attacks seedlings and the root crops), leather-jackets, and the aphid vector of the sugar-beet 'yellows' virus; a field study continued in conjunction with the Veterinary Investigation Unit, Reading, into the pre-weaning deaths of lambs; field measurements over the past two seasons have provided useful indications of the particular weather conditions in the south of England that lead to cold stress and to potential lamb losses, and also the alleviation of stress that can be provided by natural shelter on farms.

A number of monitoring studies were carried out in animal houses; these included conventional measures of animal performance in relation to environment, and initial attempts to assess the role of environment in the disease coliform mastitis.

Field diseases are commonly weather-dependent. Work continued in collaboration with the Central Veterinary Laboratory and the University of Newcastle on the timing of the peak of pasture contamination by nematodes that lead to parasitic gastro-enteritis in grazing animals. Wetness of the herbage and temperature would appear to control the rate of development of the nematode, and one problem in the move towards an operational warning system (in addition to understanding the biological process involved) lies in the establishment of criteria that use conventional and routinely reported weather data, and so avoid the need for special observations.

Other field studies related to the effectiveness of shelter against the wind. These involved the heat loss from glasshouses and the prevention of the movement of the topsoil in 'fen blows'.

On a broader time scale, work proceeded on the delineation and description of homogeneous agroclimatic areas in Scotland. This contribution to land-use planning is a counterpart to similar work done for England and Wales in earlier years. Although basic climate and working design data for field-drainage systems can now be provided for any site in England and Wales, some further fundamental work is still required. The Field Drainage Experimental Unit was provided with estimates of the time during which the soil was at field capacity, together with the excess winter rainfall for about 130 sites, in order to relate these data to dip-well measurements and to the interpretation of field-drainage experiments. Further work was carried out on the delineation of areas suitable for silage maize. Although a marginal crop, certainly in the poorer summers, maize can claim a place in many of the less intensively managed grassland areas.

Cereal and plant diseases were again given considerable priority, both by the unit at Bracknell and by the outstation staff. A fresh approach was made to the problem of forecasting in relation to potato blight, in addition to further attempts to understand the response of *Septoria* and *Rhynchosporium* to weather as indicated by the biological field data. This latter work has proved not to be simple, and further collaboration with the Plant Pathology Laboratory of MAFF (and the regional specialists) will be needed into the foreseeable future. The inference of the microclimate within stands of crops (and herbage) from standard meteorological variables such as temperatures and humidities measured in conventional screens, wind, sunshine and rainfall is a problem

touched on in connection with certain parasitic animal diseases. Because conventional meteorological data may not be sufficiently representative for the understanding of the progress of some plant and animal diseases, certain basic work was begun at Bracknell to examine the associations between the environment as measured conventionally (for synoptic and climatological purposes) and that observed within field crops.

Routine issues of agrometeorological data were made from Bracknell. These included weather summaries, estimates of soil moisture deficit, and actual and potential evapotranspiration. Information relevant to the development of a number of plant diseases was extracted from the flow of synoptic weather observations using the Meteorological Office computer system. Statements were sent daily to the Plant Disease Intelligence Unit of MAFF, to the Scottish Colleges of Agriculture and certain ADAS regional centres. Bulletins comprising the outcome of both weather monitoring and crop monitoring (provided by ADAS) were presented by the forecaster in the Sunday television 'Farming' program, and on radio. Collaboration with the Central Veterinary Laboratory provided similar statements on some animal diseases, notably liver fluke. In addition, Bracknell provided timely comment on weather-dependent farm operations. The statement at the onset of rain in August, that the outlook appeared to be for unsettled rather than for persistently wet weather, did in itself provide some guidance and comfort in what proved to be a rather difficult harvesting period.

The existence of the meteorological data banks at Bracknell meant that certain questions posed by agriculturists naturally called for work by the Headquarters unit. Throughout the year the weather extremes of 1976 were much in mind and some work was required on the significance of that year for longer-term planning in agriculture. By reference to the data banks it was possible to show agriculturists that conditions experienced in the 1976 season were a reflection of season-to-season variability rather than a consequence of a marked drift in the mean values of the main weather elements. Such variability is well known to the agricultural meteorologist, but the questions raised emphasize the value of the conventional mode of presentation of climatological data for farming purposes, which has always been to indicate the spread of values to be expected in a typical sample of years. A more specific question on the agricultural implications of a one-degree Celsius shift in mean monthly temperatures was examined, even though this is not a realistic question, certainly in the short term. This question highlights a key problem, that is the absence of quantitative models of the relation between crop response and, in particular, crop yields and weather factors. Although some comment is possible for certain crops, notably grass, the program of work at Bracknell on this topic will remain a major feature for many years.

Co-operative work and liaison contacts were maintained with all the MAFF Laboratories, many Agricultural Research Council Institutes, with universities and with Experimental Husbandry Farms and Horticultural Stations.

International co-operation was maintained through the Commission for Agricultural Meteorology of the World Meteorological Organization (WMO). In particular, a series of lectures by a member of the staff was delivered to a Technical Conference on the Potential Economic Benefits of Agricultural Meteorology, held jointly by WMO and the Food and Agriculture Organization.

Observational Requirements and Practices

The Branch, of which the Marine Division under the Marine Superintendent is a part, has overall responsibility for arranging that regular meteorological observations of suitable quality are made on land, at sea and in the upper atmosphere in sufficient numbers and with an appropriate distribution in time and space to meet national and international requirements. It specifies how meteorological sensors and observing systems shall be exposed and details the observing techniques to be employed. It arranges for observing stations to be inspected regularly to ensure that approved standards of site, instrumentation and observational procedures are maintained. The Branch establishes, on behalf of the forecasting, climatological and hydrometeorological branches, requirements for new or improved sensors, observational systems or practices, and organizes field trials to determine suitability for operational work, optimum procedures for their routine use, and the effect of their introduction on the accuracy and comparability of the basic observational data. It works closely with the Operational Instrumentation Branch on the specification of new sensors or observational systems and on the design of trials to establish the performance of prototypes.

The Branch provides the Chairman and Secretary of an internal working group concerned with reviewing the UK Observational Networks; the working group has produced important policy statements during the year on the future design and support of climatological and automatic weather station networks. In the international field the Assistant Director (Observational Practices) serves on the WMO Working Group on the Global Observing System (GOS), whilst senior Branch members serve on working groups concerned with radiation measurements and with the requirements, accuracy and quality-assurance of observational data.

Observatories

The Observatories at Kew and Lerwick and the Meteorological Office section at Eskdalemuir (a NERC Geomagnetic and Seismological Observatory) continue to make a wide range of observations of the highest quality. Additionally, the three Observatories provide valuable facilities for the impartial testing of new or improved instruments and observing techniques.

The program of work at Lerwick is the most extensive of all and includes observations of ozone, noctilucent clouds and aurora, and certain chemical constituents of air and rain. Lerwick is a designated WMO 'base-line' station for atmospheric pollution studies. The program of solar radiation observations and upper-air soundings continues and a full program of thunderstorm direction-finding as part of the UK network is now undertaken.

Observations of atmospheric potential gradient are undertaken at all three Observatories. New equipment has been procured and is under test at Kew. This features americium 241 collectors and will replace the equipment which has given good service for many years. Americium 241 has a half-life of nearly 500 years in contrast to the polonium 210 collectors now used which require replacement at intervals of a few months. The opportunity has been taken to discuss with the Cloud Physics Branch a new program of observations integrated with the work of that Branch on atmospheric pollution.

Surface observations

Several different kinds of surface observations are made to meet particular requirements. For weather analysis and forecasting purposes a network is maintained, consisting of observing stations making weather reports at fixed times agreed internationally. It is essential that such reports, known as 'synoptic' reports, should be received without delay for use in weather analysis and forecasting. The United Kingdom synoptic reporting network consists of 260 stations, of which 78 make hourly reports, and 45 make three-hourly reports, throughout the 24 hours of every day of the year. The remaining 137 stations report less frequently, some closing at night or at week-ends. Meteorological Office staff man 78 synoptic reporting stations, most of which are located at civil and military airfields. The remaining 182 stations are manned by staff of various other authorities and organizations, such as coastguards and lighthouse keepers, or by private individuals; these stations are known as auxiliary reporting stations. Special courses for training auxiliary observers in the making and reporting of weather observations are held at the Meteorological Office College. If it is not possible for an auxiliary observer to attend one of these courses, arrangements are made for instruction to be given at a nearby meteorological office, or for a member of the staff of that office to visit the auxiliary reporting station to give instruction on the spot.

There is also a requirement for records of meteorological variables to be maintained over long periods at sites representative of the various types of terrain and urban environment. These 'climatological data' provide information for the long-term averages, extreme values and frequency distribution of meteorological variables, and are used in a variety of planning activities, notably in agriculture, town planning and industry. It is, of course, important that the exposure of climatological stations should remain substantially unchanged for long periods and this is becoming increasingly difficult to ensure.

Many stations making synoptic reports submit climatological returns as well, usually for several observing hours each day. In the case of a number of WMO Reference Stations manned by Meteorological Office staff these returns cover the whole 24-hour period. About 500 other stations make climatological returns only, usually of data read at 09 GMT though some make returns for additional hours. Most climatological stations are operated by local authorities or similar organizations but a number are still operated by private individuals on a voluntary basis at their own expense. Courses for climatological observers are held at the Meteorological Office College.

For rainfall a more extensive network is required to provide the data needed to determine the distribution. This information is of great value for water use, control and planning. Data are received from about 6500 stations, most of which measure rainfall only; 68 now have magnetic-tape event recorders. The majority of rainfall stations are maintained by co-operating authorities, usually Regional Water Authorities; the remainder are operated by a variety of other authorities and by private individuals. Though the Meteorological Office operates a relatively small proportion of the total number of rain-gauges, it gathers data from all those meeting suitable standards of exposure and equipment and carries out an inspection program to ensure that suitable standards are maintained. In recent years the rate of inspection has fallen well below that shown to be necessary. The inspecting staff has therefore been increased but, although the inspections are now more frequent, improvements are still needed.

In order to assist the forecasting of weather conditions along major roads a network of 80 stations has been set up providing plain-language reports (PLAINOB). Of these, 51 are at road maintenance depots alongside motorways, 15 are at Automobile Association and Royal Automobile Club offices and 14 are at other locations. Reports are made at approximately three-hourly intervals during daylight hours throughout the year and are also made during the night in winter months. Regular inspections of these stations are now taking place.

Lengthy trials, recently concluded, have shown that automatic weather stations are now sufficiently reliable and accurate to be used to supplement the surface observing system. They cannot yet give the wide range of observations provided by the human observer but they provide the only means of gathering synoptic data in circumstances where it is difficult or unduly expensive to support human observers. Thirteen automatic weather stations are being installed and plans have been made to procure others to respond to the proposals of the Working Group on UK Observational Networks.

Observations are required from the North Sea to support the specialized forecasting service given to the offshore industry. Two officers have therefore been established to advise the offshore gas and oil industries on meteorological instrumentation and observational procedures. One is based at Aberdeen and deals with installations within the United Kingdom offshore area north of latitude 55°N. The second is based at Bracknell and deals with installations south of latitude 55°N. The major effort is directed towards obtaining regular good-quality observations from the fixed production platforms for both synoptic and climatological purposes, although advice is also freely given to the more transitory drilling rigs. Both officers work closely with the London Weather Centre. Courses for observers from offshore structures have been run at the Meteorological Office College.

Particular efforts were made during the year to increase the frequency of inspections of co-operating stations by temporarily transferring staff from other duties. As a result, all climatological and auxiliary stations were inspected during the year; this has never previously been achieved. Additionally, the rate of inspection of rain-gauges has been more than doubled.

Radiation observations

There is a long history of solar and terrestrial surface radiation measurements in the Office, notably at Kew Observatory, but it was not until the 1950s that systematic observations were made at a number of stations. The official network now consists of seven stations in the United Kingdom and the station at Malta. The plan to open six new stations has been delayed by faults in the new equipment procured but these have now been overcome and preparations are well advanced. Radiation observations at North Atlantic Ocean Station 'L' (57°N, 20°W) ceased with the introduction of the refurbished ocean weather ships during the year, again because of the faults mentioned above. However, it is hoped to resume measurements during 1978.

There are now 22 co-operating stations operated by authorities having a hydrological or agricultural interest. These provide data, some in the form of hourly totals, for which the Office operates quality-control procedures. Regular liaison visits are made to these stations and the Office offers an instrument calibration and repair service with the object of securing homogeneous data throughout the network.

Reliable radiation measurements of suitable accuracy can only be achieved by painstaking daily attention to instruments, by frequent calibration of both recording circuits and instruments against sub-standards. The sub-standards are regularly compared with the national standard which has been embodied in a family of Ångström pyrheliometers for many years. Recent experience in international comparisons of national standards has led the Office to acquire a new conical-cavity absolute radiometer (PACRAD) which has been successfully brought into service.

An experiment is in progress in which observations from a dense array of ten temporary autographic radiation stations are being used to devise methods of interpolating between observations made by a more permanent widely spread network of stations. Observations are being made to check methods of calculating radiation on vertical surfaces from the more plentiful measurements on horizontal surfaces.

Observations of solar ultra-violet radiation in bands centred on 315, 350 and 400 nanometres have begun at Beaufort Park in response to growing national interest in this region of the solar spectrum, but there are well-known instrumental difficulties to be overcome. At present there are no plans for measurements at other stations.

National and international interest in possible applications of solar energy has continued and a senior officer of the Branch has been active in a WMO Regional Association VI Working Group, in the EEC Solar Radiation Data Acquisition Group and in an International Energy Agency Task Group.

Runway visual range

At many airfields Air Traffic Control staff or other non-meteorological staff assess the 'runway visual range' in poor visibility with the aid of lights at known distances. The Meteorological Office provides a service of inspection and calibration of these installations for the Civil Aviation Authority and the Royal Air Force. The calibration is necessary to establish the relationship between the number of 'RVR reference lights' the observer can see and the distance along the runway the pilot of an aircraft can see from the 'touch-down zone'. Twice-yearly visits are made to 32 civil airports in the United Kingdom and to 35 RAF stations at home and abroad.

Upper-air observations

The normal program of upper-air observations comprises pressure, temperature and humidity soundings by radiosonde at 00 and 12 GMT and upper-wind measurements by radar at 00, 06, 12 and 18 GMT. This program was maintained by eight stations in the United Kingdom and those at Malta and Gibraltar.

The program of upper-air observations, using the Mk 2b radiosonde and ships' radar, was maintained on the North Atlantic Ocean Station 'L' (57°N, 20°W) by the ocean weather ships *Weather Reporter* and *Weather Surveyor* for the first part of the year. These ships were then replaced by the refurbished ships *Admiral FitzRoy* (see Plate II) and *Admiral Beaufort* which are equipped with new radiosonde/wind-finding equipment based on the NAVAID system (see Plate III, lower). This system obviates the use of radar and is partially automated, enabling a reduction of two members of staff to be made on each ship.

Close liaison was maintained with the International and Planning Branch

which has established upper-air stations overseas as part of the UK contribution to the World Weather Watch program. One of these stations, at Mahé in the Seychelles, was the subject of a visit of inspection. The new upper-air station at St Helena became operational on 15 March 1977.

Assistance was given in September to the Operational Instrumentation Branch during tests of the new Mk 3 radiosonde system (destined to replace the Mk 2b system at all UK stations and at Gibraltar) and, in October, during the conversion to the new system at Aughton. Operational use of this new, fully automated radiosonde system at Aughton began in November.

Thunderstorm location and surveillance

A full program of half-hourly observations by day and hourly observations by night was maintained throughout the year by the network of cathode-ray direction-finding (CRDF) stations at Lerwick, Shanwell, Camborne, Hemsby, Gibraltar and Malta. The area for which reports are made was restricted in the east to longitude 30°E and in the south to latitude 25°N, the quality of location fixes beyond those limits being degraded by the closure of the Cyprus station in 1976.

A program of refurbishing of the obsolescent equipment now in use was completed during the year in order to maintain the quality of reports until a new automatic system is developed and becomes operational in the early 1980s. A theoretical study of the performance to be expected with several alternative networks of stations was completed. Methods were developed for the processing of position-line data by computer to yield a best estimate of lightning location. These methods are applicable to the current operational system and a trial will shortly take place to investigate the advantages to be gained by doing so.

Arising from a United Kingdom suggestion, the World Meteorological Organization agreed to change the communication code used to report the locations of lightning flashes to other countries, in order that the unique results of the British system may best be reported. The change will come into effect on 1 January 1978 and makes provision for reporting the number of flashes observed for each location. In this way differences in the lightning activity between geographical areas can be better represented.

User trials of new equipments

Following the development or procurement of new sensors or equipments, field trials have been carried out throughout the year to determine the quality and reliability of these devices when in routine use. As already mentioned, a prolonged trial of the Meteorological Office automatic weather station equipment was concluded satisfactorily. For those variables observed, the system was found to report with a consistency and accuracy comparable with human observations.

A joint trial has been conducted with the Operational Instrumentation Branch to assess the feasibility of using a laser beam to measure the height of cloud bases. The basic technique has been validated and, if a system can be brought to an operationally acceptable performance, benefits will accrue from the greater accuracy of measurement and the elimination of the long base-lines which are required by the present nodding-beam system.

Other trials were conducted of various types of digital temperature indicators, meteorological marine buoys, other forms of automatic weather stations for

climatological and hydrological purposes, new thermometer enclosures, rain-gauges and a mean wind-speed indicator.

Marine Division

The numerical strength of the Voluntary Observing Fleet has remained almost static throughout the year. Most of the effort of maintaining the strength of the Fleet rests on the seven Port Meteorological Officers at Glasgow, Liverpool, Hull, Tyne, Cardiff, Southampton and London. These officers have found that frequently the number of new ships recruited to the scheme is equalled by the number of withdrawals which occur when ships are sold or laid up for long periods. Nevertheless the number of observations received has continued to increase because the majority of vessels now spend more time at sea than their predecessors. Meteorological work at sea in British merchant ships has always been carried out on a voluntary basis and it is gratifying to note that the standard of observing has been well maintained throughout the year. The policy of appointing Port Meteorological Officers who are master mariners with considerable experience as voluntary observers at sea contributes significantly to the high standard of observations received from the Fleet. The installation of distant-reading meteorological equipment in a number of ships under construction, in order to ease the work-load of observing officers, has continued with the wholehearted support and co-operation of shipowners.

A set of basic meteorological instruments and special stationery were supplied to a selection of the yachts participating in the Whitbread Round-the-world Race and arrangements were made for special forecasts and warnings to be broadcast to the yachts from Portishead Radio each day until the majority of competitors had crossed the equator when a similar forecasting service was provided by the South African meteorological and radio organizations.

Acknowledgement should once again be made of the valuable service rendered by many Commonwealth and foreign Port Meteorological Officers for their services in the replacement of defective instruments in UK Selected Ships on protracted voyages, and the withdrawal of instruments from British ships which have been sold abroad to foreign interests. The timely intervention of the foreign Port Meteorological Officers has been of great assistance as the number of vessels ending their British sea-going career in ports abroad has continued to increase.

The shipmasters, principal observing officers and radio officers who have been responsible for sending in the 100 best meteorological logbooks during the year were, as is customary, nominated for 'Excellent' awards. Barographs were presented to four shipmasters for their long and zealous meteorological work at sea. Awards were also made to masters and officers of vessels on the short sea trades for their contribution in making sea-temperature observations and to trawler skippers and radio officers who had the best records in making and sending non-instrumental observations from the fishing regions.

The number of marine enquiries, most of them from solicitors, shipping companies, universities and industrial firms, has continued to increase throughout the year and totalled more than 500. The subjects of enquiries are extremely varied.

The *Marine Observer* was published quarterly as hitherto and continues to be well received.

The United Kingdom continued to operate two ocean weather ships throughout the year under the WMO North Atlantic Ocean Stations Agree-

ment. At the beginning of the year the *Weather Surveyor* and *Weather Reporter* were in service whilst the *Weather Adviser* and *Weather Monitor* were undergoing extensive refits and modernization in Manchester Dry Docks. The purpose of the refits was to extend the serviceable lives of the ships for a number of years and to improve the living and working conditions for those on board. As the ships are 33 years old and underwent a limited conversion 18 years ago a vast amount of work was necessary to raise the standards of accommodation and technical equipment to those found in modern ships of the same size.

The ships were completely rewired, the electrical generating systems being renewed and changed from direct to alternating current. The balloon shelters were raised to a higher deck and the use of hydrogen as a balloon gas was discontinued in favour of helium. The radars used previously for upper wind-finding were replaced by NAVAID systems, making it possible to reduce the size of the ships' complements. A further saving in personnel was achieved by fitting automatic controls to the boilers. The reductions in crew made it possible, after stripping and refitting part of the accommodation, to provide single-berth cabins for all adult members of the crews. Further improvements for crew comfort and entertainment included the fitting of completely new galleys, the provision of crew recreation rooms and video-tape television in crew messes and the wardrooms. The opportunity was taken to strip the radio and transmitting cabins and to refit with modern equipment providing links from the ships to coastal radio stations and to the Bracknell Telecommunication Centre (see Plate III, upper). Navigating bridges were removed and combined wheelhouse/chartrooms constructed and equipped with modern navigational aids and equipment. On the completion of satisfactory sea trials the ships were renamed OWS *Admiral FitzRoy* (see Plate II) and *Admiral Beaufort* respectively.

Three Quays Marine Services, being the technical services division of the P. & O. Group, were employed as consultants throughout the refits and they provided most satisfactory guidance and technical assistance.

The *Admiral FitzRoy* (ex *Weather Adviser*) sailed on her first voyage under her new name on 17 March, replacing the *Weather Surveyor*, and was followed by the *Admiral Beaufort* (ex *Weather Monitor*) which sailed on 28 May, replacing the *Weather Reporter*, the oldest of the Castle class frigates. Ocean Station 'L' was manned continuously throughout the year except for some disruption following a fire on OWS *Admiral FitzRoy* during November.

The weather ships make hourly surface and six-hourly upper-air observations (for heights reached in upper-air ascents see Table V on page 65). The following additional observations were made at regular intervals by the two British weather ships: sea temperature and salinity to considerable depths, collection of rain water for analysis by the International Atomic Energy Agency, magnetic variation, samples of sea water at monthly intervals collected for an International Atomic Energy/WMO tritium survey, sea-water samples collected during passage to and from station for monitoring radioactive content, and reports of floating pollutants for the Intergovernmental Oceanographic Commission/WMO pilot project on marine pollution monitoring. In addition, sea and swell recordings were undertaken throughout the year using the Tucker ship-borne wave-recorder. Recording of solar radiation was maintained on the *Weather Surveyor* and the *Weather Reporter* until they were withdrawn from service. The refitted ships will be provided with new equipment to continue this work as soon as it becomes available.

Operational Instrumentation

The Branch is responsible for meeting the needs of the user branches for meteorological instruments and data-acquisition systems. The requirements of these branches are examined in close co-operation with the Observational Requirements and Practices Branch, and either the most suitable system composed of existing sensors, data-acquisition modules and observational techniques is chosen, or an Operational Requirement defining the need for a new development area is raised.

The Operational Instrumentation Branch then carries out the necessary design, development and/or adaptation of equipment required to meet the application. When prototypes and pre-production equipments have successfully passed their trials, or suitable equipment is already available commercially, manufacturing contracts are placed for a production quantity of equipment. The Branch is then responsible for the technical progressing of the contract, for acceptance testing and calibration of the equipment on delivery, for planning and installation in the field, and finally for maintaining and servicing the equipment on the outstations and for making subsequent 'post-design' modifications throughout its life.

Two aspects of the work in the Branch deserve special mention this year: the start of operational service for the Mk 3 radiosonde system, and the completion of a trials program of a commercial prototype laser cloud-base recorder (ceilometer).

The commencement of routine operational Mk 3 radiosonde flights at Aughton is the fruit of a sustained effort by the project team over several years. The prototype ground station at Beaufort Park has now been operating successfully for over twelve months, and has been used to complete the development and testing of the operational software suite (see Plates IV and V). This task proved more difficult than had been expected, and it was not until September 1977, when an extensive software trial involving a total of 168 hours of program-run time had been completed, that the program was considered suitable for routine use. During the 168-hour trial a total of 47 flights to heights of up to 7 mb were completed in the space of 15 days, and, apart from the prime function of testing the system software, a valuable set of archive data was obtained which is now available for research purposes.

The installation and commissioning of the first operational station (Aughton) was completed in early October 1977 and, following a three-week training period, operational flights began in early November. The ground-station hardware for the next six stations had completed their 1000-hour 'burn-in' in the manufacturer's factory by the end of the year. The second station, at Crawley, is due to be installed in February 1978, and thereafter stations are to be converted at approximately monthly intervals, so that the entire network will be operational by early 1979.

The central calibration facility at the Headquarters Annexe in Eastern Road has been producing Mk 3 radiosonde calibrated transducers of operational quality since October 1977 but, because of a minor hardware-design fault and some software difficulties early in the year, final acceptance testing by the Branch has been delayed and is now scheduled for March 1978. The calibration plant is, however, already fully operational with a maximum capacity of 550 pressure units and 550 pressure reference units per week.

The completion of the final phases of the Mk 3 radiosonde project can be contrasted with the work on laser cloud-base recorders which is only in its initial trial phase. The existing nodding-beam cloud-base recorders (CBRs) are now coming to the end of their design life, and it has been necessary to establish whether the physical principle used in a new commercial development, the laser cloud-base recorder (LCBR), is suitable for use in operational conditions and whether it meets the needs of the user in terms of accuracy and reliability. Two prototype LCBRs were purchased in 1976, and a trial was carried out during 1977 in which the laser devices have been compared with the standard nodding-beam Mk 3 CBRs at Beaufort Park, Birmingham Airport, Cardington and Dyce Airport. Thus the LCBR principle has been evaluated in environments ranging from an industrial atmosphere to clean country air. The results have indicated that the laser systems used are accurate range-determining devices, but that the prototypes had inadequacies at the limits of their range. Some problems appeared to exist in detecting cloud during rain. The next stage will be to prepare a suitable Requirement Specification for an LCBR to meet the needs of the user branches.

Co-operative projects: international

Preparations for the Seventh Session of the World Meteorological Organization Commission for Instruments and Methods of Observation (CIMO-VII) were started early in the year. They involved three senior members of the Branch, together with a similar number from the Observational Requirements and Practices Branch. Four scientific papers were written by members of the Office for presentation at the Technical Conference (TECIMO) preceding the Commission sessions, and several working papers were also prepared. The meeting took place from 27 July to 12 August in Hamburg, and a three-man delegation from the United Kingdom attended. Five officers of the Office were subsequently appointed as members of CIMO Working Groups or as Rapporteurs.

The Branch continued to be involved throughout the year in discussions on two projects under the European Economic Community scheme for Co-operation in Science and Technology (COST). Under the project concerned with the setting up of a European network of oceanographic/meteorological data buoys (COST Project 43) an international Agreement was prepared, defining a 4-year experimental pilot project. There have been many problems in finding acceptable terms for all the participating countries but it is hoped that the Agreement will have sufficient signatures to become valid by early 1978. In the meantime, a preliminary plan for the dissemination of the data from existing European Ocean Data Acquisition Systems (ODAS) between the COST countries has been prepared.

As part of the UK participation in COST 43 a joint co-operative trial has been set up between the Norwegian Christian Michelsen Institute, the Directorate of Naval Oceanography and Meteorology (DNOM), and the Meteorological Office. The trial will consist of comparing a Norwegian buoy with a British buoy at position 59°30'N, 06°00'W to determine the most suitable high-frequency transmission system to use, and to make an intercomparison of the sensors and system performance. The trial is due to take place during 1978.

It has been a quiet year for the second European project, COST Project 72,

which deals with the standardization of meteorological instruments within western Europe. Approval was given by the inter-government Senior Officials Committee for studies to be carried out in three areas:

(a) new sensors for use with automatic weather stations and in severe environments;
(b) remote sensing, particularly in the planetary boundary layer; and
(c) the problems associated with setting up a European weather-radar network.

A senior officer of the Branch attended a meeting of the Technical Committee in November to discuss the preliminary drafts and future steps.

Co-operative projects: national

Two senior officers of the Branch participated in meetings of the Standing Committee on Ocean Data Stations (SCODS). The Committee discussed the possibility of integrating the future plans concerned with Ocean Data Acquisition Systems (ODAS) of various UK Government Departments, and produced a proposal for a coherent overall strategy. This proposal will now be put to the Heads of the various Departments involved.

Work has continued in support of members of the United Kingdom Offshore Operators Association (UKOOA). Good progress has been made on a microprocessor-based automatic weather station (AWS) for installation on Mobil's Beryl A oil-production platform, utilizing an existing suite of meteorological sensors. A contract was placed to instrument Occidental's Piper A oil-production platform with sensors supplied by the Meteorological Office, for use later with a further AWS. Negotiations should shortly be concluded with Amoco to place a third AWS and sensors on the 49/27A production Gas Platform. It is hoped that two other suitable platforms can be found on which to instal conventional non-automatic instrumentation.

Plans to instrument the North-west Shingles Beacon in the Thames Estuary with an automatic weather station have been changed, following the discovery by Trinity House that the beacon structure has subsided into the sands by two metres, and is likely to continue to subside. Alternative sites have been considered, and it has been decided to instrument the Whitaker Beacon off the Essex coast.

The Branch has also been negotiating with Trinity House for the installation of automatic weather stations on a number of the Trinity House LANBY buoys, which are designed to take over the role previously carried out by manned lightships.

A 2½-metre diameter toroidal wave-rider buoy (ODAS 1), fitted with a NIMBUS-6 buoy Transmit Terminal, was deployed in Lyme Bay in the English Channel by MOD(N) in March 1977. Following satisfactory 'survivability' trials it was replaced in June by a similar buoy (ODAS 2) with a full suite of meteorological sensors. The receiving station for its VHF transmission system has been installed in the meteorological office at RNAS Portland, and it is planned to extend this link to the London Weather Centre during 1978.

The Branch has also continued to participate in the UK Data Buoy Project in which the Department of Industry takes a leading role. Following 18 months of operation at sea off the Norfolk coast, the buoy (DB 1) was towed to

Blackwall Docks in April 1977 for refurbishment. A duplicate suite of meteorological sensors and interfaces has been fitted, and it is expected that the buoy will be moored in its new location, 140 miles to the south-west of Land's End, during 1978. In support of this, officers of the Branch have been involved in the arrangements for locating a new receiving station at RNAS Culdrose, and in high-frequency transmission tests between Blackwall and Culdrose. A land-line link is being arranged by the contractors (Seatek) from Culdrose to a computer centre at Woking, and it is hoped that both the London Weather Centre and the meteorological office at RNAS Culdrose will be able to access the synoptic meteorological data hourly.

Two of the five drifting buoys launched in 1976 were recovered, and plans for MOD(N), MAFF, the Institute of Oceanographic Sciences and the Meteorological Office to refurbish the hulls and electronics as a co-operative venture are under way. It is proposed that they should be re-launched in the eastern Atlantic during the Joint Air–Sea Interaction (JASIN) exercise in 1978.

Finally, the Branch has continued its co-operation with Heriot-Watt University and the Institute of Hydrology in the 3-year automatic weather station development project for severe environments on the summit of Cairn Gorm. The Office supplied the VHF telecommunication link, and has offered to take over the maintenance of the station if the project proves successful. The evaluation of the prototype against a known sensor system at Leuchars has been delayed temporarily until Heriot-Watt University can make it available.

Development, production and evaluation of new instruments and systems

The two refurbished ocean weather ships were equipped with fully operational NAVAID wind-finding equipment when they sailed on their maiden voyages. Comprehensive documentation in the form of test specifications has been developed for these sets and is now in routine use. A third NAVAID equipment has been procured against a specification written by the Branch in consultation with the users and, as a result of close liaison with the manufacturer, including a visit to his factory in America by a senior member of the staff, many of the deficiencies in the original software have been eliminated. The modification by the manufacturer of one of the two original equipments to meet the new specification is due in spring 1978, but work on the other system has been delayed so that it may be used in unmodified form for the JASIN experiment in mid-1978.

Following the preliminary work on automating the thunderstorm location system reported last year, a decision has been taken to mount an experimental trial of a system based upon the measurement of the difference in the arrival time of the lightning-generated radio wave at four locations. Work on the design of the hardware for the trials stations is almost complete, and the production of the hardware is well advanced. The necessary software development is progressing more slowly. It is hoped that the trial will be undertaken in the summer of 1978, but it is possible that it will be necessary to extend the period of experimental measurement until mid-1979. The final decision on whether to re-equip the existing operational network with an automated system based upon time-of-arrival difference techniques will depend upon the outcome of the trial.

The three digital anemograph logging equipments (DALE) continued in operation throughout the year at Stornoway, Valley and Boscombe Down.

The equipment has been modified in the light of field experience and a production prototype was manufactured 'in-house' to prove the final drawings. Procurement action for a further 20 equipments is in hand.

Twelve replacement data-logging equipments (MODLE 3) for all radiation recording stations in the network were delivered early in the year. Operational problems occurred during the acceptance testing, and it was necessary to return the equipments to the manufacturer for modifications. After extensive environmental tests the twelve systems have now been returned to the Office and they will be installed at outstations early in 1978. With regard to the radiation network, a decision was made to equip certain of the Meteorological Office Weather Observing System (MOWOS) automatic weather stations with radiometers. An interface was designed and developed 'in-house' to provide this capability.

Work on the development of automatic weather station (AWS) systems has continued. Apart from the AWS for oil platforms mentioned previously, two continuous automatic remote display (CARD) automatic weather stations were installed and commissioned at the RAF ranges at Theddlethorpe and Wainfleet in Lincolnshire. These AWS are providing field-trial data direct to the offices at Binbrook and Coningsby. Planning continues for further installations at the Otterburn and Sennybridge Army ranges. Also the CARD transmission system between Beaufort Park and the HQ London Road building in Bracknell was modified during the year to allow continuous logging of winds and temperatures for climatological purposes. Development work on two prototype automatic climatological recording equipments (ACRE) has been started. Considerable effort has also been put into solving the problems associated with the introduction of automatic or semi-automatic data acquisition and transmission systems on UK-registered merchant ships. Increasing automation on these ships is creating a general reduction in the number of deck officers available to make observations and radio officers to communicate them, so work has been started with a view both to modifying the land-based microprocessor AWS for ship use and also to the automatic transmission of the data. Trials have been arranged which involve the modification for automatic use of the HF wireless telegraphy equipment on two of the voluntary observing Selected Ships. The use of communication satellites for this role is also being actively considered.

In the sensor-development area the principal activity has been in evaluation trials. The laser cloud-base recorder trials have already been mentioned, and the other major effort has been in a trial of three commercially available visibility measurement devices, each sampling a relatively short baseline and using different principles. The trial results have been analysed, and a report and assessment of the representivity and reliability of the various equipments will be issued early in 1978. Thought has been given to possible types of present-weather sensor for use with automatic weather stations, in particular with regard to the detection of precipitation and cloud cover. Work has started on the evaluation of slow-scan television techniques, by which a fairly low definition picture can be transmitted via telephone lines.

Technical management and services

One of the main responsibilities of the Branch is to provide continuing technical services and facilities to all user branches within the Meteorological Office as well as its own development sections. These services include the

technical aspects of procurement, technical documentation, routine test and calibration, installation, maintenance, post-design services, and the provision of mechanical and electronic workshop facilities.

The activity in the Engineering Drawing Office and the Mechanical Workshops continued at a high level despite some staffing difficulties. The policy of using contract draughting firms to provide the major effort in design and drawing has been very successful in view of the range of materials and processes used in modern meteorological equipment. The policy permits the use of experts in the various fields as required, and is demonstrably cost-effective. The facilities of the Mechanical Workshops were improved by the addition of argon-arc welding equipment during the year.

The procurement activity associated with the Mk 5 Wind Systems was delayed owing to some changes in the overall requirements and to a few late modifications in the design. Procurement action for 12 systems has now commenced. These systems allow wind data to be transmitted over long distances, and have the flexibility of permitting a variety of different displays to be used. Concern has been felt for some years at the difficulty of checking anemometer systems which can involve complex wiring and switching arrangements on the major airfields. An anemometer calibrator has now been developed for use by the Maintenance Organization (formerly called the Regional Servicing Organization (see page 46)).

The automatic weather station at the IBA 300-metre mast at Lichfield continued to provide experimental data from four different heights and to transmit the data to Birmingham Airport. The results have been sufficiently encouraging to warrant a further semi-operational trial period. A serious problem with the MOWOS equipments at Holme Moss, caused by interference from the BBC transmitter, was solved by screening the cabin with a metal-foil lining.

Cossor wind-finding radars are in use at all the routine upper-air stations, at the South Uist range and at three MOD(PE) and Army stations. They continue to give very good service although some sets are now over 12 years old. It is now hoped that they can be retained in operation for a further 12–13 years, and the manufacturers have been asked to make a study of the equipment, to advise on the action to be taken to ensure component availability, and to propose modifications to parts which may give trouble because of wear or obsolescence. Refurbishing of moving parts which are showing signs of age is already being undertaken in the Branch.

The installation at Camborne of the Plessey Type 43S weather radar recovered from Singapore was completed. The computer system and peripherals for measuring precipitation and transmitting the data are being commissioned by our Radar Research Laboratory (RRL) and the Royal Signals and Radar Establishment (RSRE), and it is anticipated that the complete system will become operational early in 1978. Initially, data will be relayed to the meteorological office at Mount Batten, to the RRL at Malvern and to the South West Water Authority who are co-operating in the provision of suitable calibrating rain-gauge sites.

Installation at RAF Upavon of a mobile Type 43S radar, previously used for research work, has been delayed by difficulties in funding works services, but the Wessex Water Authority are interested in the data and have offered to carry out most of the work as a contribution to the project.

The Branch plays an active part in the Radar Network Facilities and Operational Liaison Group set up to deal with these projects.

A suitable site is being sought in south-east England to install a C-band radar which has been offered on long-term loan by Plessey Radar Ltd. This will give coverage over the area of Greater London and a large part of the Home Counties. It will provide useful information to London/Heathrow and London/Gatwick Airports, and to the Central Forecasting Office at Bracknell as well as the London Weather Centre.

The Meteorological Office is one of five participants in the North-west (Hameldon Hill) Radar project, the others being the Central Water Planning Unit, the Water Research Centre, the Ministry of Agriculture, Fisheries and Food, and the North West Water Authority. This will be the first of the new generation of unmanned radar stations working on an operational basis. It derives from the experience gained in the Dee Weather Radar project and the development work done within the Office at RSRE, Malvern. A senior officer of the Operational Instrumentation Branch is playing an active part in the planning stage and the Branch will be responsible for the installation and maintenance of the equipment which will be sited at Hameldon Hill, south-west of Burnley, Lancashire, at a height of 399 metres.

Testing of upper-air balloons has continued. The quality of natural rubber balloons has been variable; in particular, the larger type has occasionally been of poor quality. Synthetic rubber balloons have exhibited improved quality.

The Test and Calibration section is in a period of transition as the Mk 2b radiosonde calibration work runs down and the Mk 3 radiosonde calibration plant is brought into full operation. Skinning and seasoning of the Mk 3 radiosonde humidity elements has now commenced. A new environmental humidity cabinet has been acquired for the test laboratory which will give a range of humidity conditions at temperatures between −25 °C and +50 °C.

A start has been made on rewriting Part I (Instruments for surface observations) of the *Handbook of Meteorological Instruments.*

Accommodation has been allocated in the HQ building in London Road, Bracknell, for a display of antique meteorological instruments. A number of old instruments have been located and this Museum of Meteorological Instruments will be opened as soon as suitable furniture for display is available.

Maintenance and technical training

The Meteorological Office Maintenance Organization, formerly known as the Regional Servicing Organization, has continued to provide technical support at home and overseas in close liaison with the user branches. The maintenance of the Myriad computer-based message-switching system (AUTOCOM) was taken over from Marconi during the year, and responsibility for the technical support at the Ocean Weather Ship Base at Greenock was also transferred to the Branch. With these changes, the Maintenance Organization is now responsible for the maintenance of all the meteorological equipment used operationally by the Office.

In order to meet the management and control requirements of such a widespread organization (from the Shetland Islands to the Pacific), the Headquarters cell has been reorganized to include a Group Technical Officer (TTO I) with responsibility for much of the routine work, as well as the Chief Technical Officer (TTO A) who is in overall charge of maintenance policy and

control. The variety of equipment being maintained by the Maintenance Organization now ranges from radars and computer-based systems to anemometers and rain-gauges, and the work requires technical expertise as well as careful planning and organization.

Technical training has been a very active area this year. A full Assistant Scientific Officer/Radio (Meteorological) Technician conversion course has been held, and an innovation has been the use of the Meteorological Office College facilities at Shinfield Park, near Reading, for the theoretical part of the course. It is hoped that the residential nature of the course will be beneficial. The emphasis of other courses in 1977 has been on the principles of computers and microprocessors. The need for technical competence in the area of data processors has grown rapidly in the last two or three years and is now relevant throughout the Office. The new Technical Education Council proposals for courses and examinations to replace Higher National Certificates and City and Guilds Certificates have led to discussions with local colleges on the further education requirements of Office staff in this field.

Computing and Data Processing

The Data Processing Branch is responsible for operating the main computer system of the Office, known as COSMOS, and for the software needed for its operation, including that of typewriter and visual display unit (VDU) terminals. It is also responsible for general-purpose programs to store, control the quality of, and retrieve observational data received in real time from the telecommunication system, and to produce plotted and line-drawn charts and graphical displays required for operational tasks and some research work. An advisory service is provided for COSMOS users and there is a limited service of data extraction from machinable archives to provide meteorological data for use by other agencies. The Branch also operates the processor-controlled key-to-disc data entry system (PCK) and the punched-card unit.

As in the previous year, considerable effort was applied to performance monitoring, the earlier results of which led to magnetic disc and tape upgrades in March. Consideration of the current work-load, back-up facilities for operational work, terminal response times, and the plans for automation at some major outstations, all led to the conclusion that some increase in computing resources was necessary. A detailed study indicated that the prime need, and also the most cost-effective solution, was an increase in main storage on both processors and the provision of some dedicated fast-backing storage on the smaller machine. (Authority for these additions was obtained late in the year and installation is expected in the second quarter of 1978.)

Losses of experienced staff caused delay in the implementation of operating system changes, and a general shortage of staff with knowledge of computer programming led to the introduction of training courses at the Meteorological Office College.

The COSMOS computing installation

The COSMOS computing system is based on the fast IBM 360/195 computer, coupled to the smaller IBM 370/158 computer. The latter, although having only one-fifth of the power of the former, releases the main processor for the more demanding work such as computing for numerical models of the

atmosphere; however, when the main 360/195 processor is unserviceable, the 370/158 has sufficient power to provide a back-up service for essential operational work. In normal operations the smaller processor provides line-drawing, plotting and remote-terminals services, undertakes the computation for most of the smaller tasks, and handles all input and output requirements. The two processors share most of the 20 disc drives, the fixed-head disc, and ten of the magnetic-tape drives. Although, normally, all input and output devices are connected to the smaller processor, they may be switched to the 360/195 if the 370/158 fails.

In the first quarter of the year the following hardware changes were made: the KDF9 magnetic-tape units were withdrawn, four telex 6250/1600 bits per inch tape drives were introduced, and four IBM disc units were modified to take double-density discs. A computer link magnetic-tape cleaner/evaluator was also brought into service for magnetic-tape maintenance. In the last quarter a new IBM System 7 computer, with an attached disc, was implemented as the interface between COSMOS and the Marconi Myriad computers in the Telecommunication Centre. Plans were also made to increase the main storage on both COSMOS computers in early 1978 and to add some dedicated fast-backing store to the smaller machine.

Three operating systems are required to operate the coupled twin-processor system: the Asymmetric Multiprocessing System (ASP) to control the flow of work to and from the two processors, the Virtual Storage System (VS2) to control the work done in the 370/158, and the Multiprogramming System with a Variable Number of Tasks (MVT) to supervise the work done in the 360/195. Later versions of VS2 and ASP were introduced, mainly to provide support for new hardware. Also, towards the end of the year, assessments were started of the Job Entry Sub-system 3 (JES 3), to replace ASP, and of Multiple Virtual Storage (MVS), to replace VS2. About 30 000 jobs are submitted each month, either from terminals, from the card reader in the Receipt/Despatch area, or as scheduled operational tasks.

The 360/195 and 370/158 computers and their peripheral equipment continued to give generally reliable service. The serviceability of the 360/195 exceeded 98 per cent, except in September when over 30 hours were lost owing to faults in the central processor unit (CPU). The serviceability of the 370/158 also exceeded 98 per cent, except in July when over 30 hours were lost, mostly owing to failures in the CPU internal power unit. Several other faults also occurred in July following failures in the mains electrical supply during intense electrical storms.

Support for computer-based applications

Most terminals are supported by time-sharing option (TSO) software. An average of about 2800 user sessions each month took place on remote terminals which are now used extensively by programmers for program development, by non-programming staff for extraction of data to answer enquiries, and by operations staff to monitor and use real-time data in the Telecommunication Branch and the Central Forecasting Office (CFO). The PDP 11/34 mini-computer in the National Meteorological Library was connected to COSMOS in August (see also page 53), and a link to the Honeywell computer at the Institute of Oceanographic Sciences at Bidston was established in October, in preparation for experiments in the real-time forecasting of North Sea storm surges early

next year. Support for the terminal at HQ Strike Command was extended to 24 hours a day on an experimental basis; also, for a short period during the operational trials of the Mk 3 radiosonde system, the Beaufort Park terminal was similarly supported. Modifications to TSO, written by the Post Office and applied in August, created some improvement in terminal response times, but the problems which remain during the busy afternoon periods cannot be solved until the 370/158 storage has been expanded.

In October the System 7, which provides the interface between COSMOS and the automated telecommunication complex (AUTOCOM), was replaced by a similar but larger system with disc storage. The new System 7 provides the means to store several hours of data on-line and enables rapid recovery after a breakdown.

The data supplied to COSMOS through the System 7 interface are captured by the synoptic data bank (SDB) programs which store and control the quality of real-time observational data in preparation for their use, operationally, in analysis and forecasting programs and for their presentation to forecasters in various ways. The most time-critical operation is the automatic plotting of hourly charts of British Isles surface observations, particularly those for facsimile transmission to forecasting offices throughout the British Isles. To meet this requirement the SDB suite of programs is designed so that data can be processed in an almost continuous stream from AUTOCOM for input to the chart-plotting programs. This imposes a heavy demand on computer main storage and, in February, a redesigned program suite was introduced which reduced the storage requirements from 360 to 240 kilobytes. The reduction in storage is critically important when the 370/158 is unavailable and the SDB must operate in the 360/195 which has a store of only one megabyte. The continued expansion of time-critical operations underlines the need for the data monitoring introduced last year in the three operational areas, Telecommunications, COSMOS and CFO.

The plans to install automated systems at the Principal Forecasting Offices at London/Heathrow Airport and HQ Strike Command (HQSTC) at High Wycombe will necessitate some changes in the interface between AUTOCOM and COSMOS to connect, with the minimum number of lines, Heathrow and HQSTC to both computing complexes. The same interface will also (in 1978) connect the European Centre for Medium-range Weather Forecasts (ECMWF) near Reading. In July new WMO codes were introduced for the international exchange of data received from meteorological satellites. The new generation of satellites now coming into use will provide large increases of data, and a separate data bank is to be established to provide greater flexibility and scope for expansion.

The Calcomp 1670 computer output on microfilm (COM) equipment and 1136 drum plotters continue to play an important role in the graphical presentation of data to forecasters. With the development of a generalized plotting program, it is now possible to plot upper-air data for any standard level, on charts of any scale, for any part of the globe; 14 000 such charts were produced during the year for CFO—an increase of about 100 per cent on 1976. Over 40 000 charts of surface data were plotted, mostly for CFO, but many were also broadcast by facsimile to outstations.

A Calcomp 960 plotter was purchased in December to replace one of the two 1136 drum plotters which are nearing the end of their useful life. The 960 is a

fast inclined flat-bed plotter which draws on plain or pre-printed stationery. It will be used to produce the high-quality plotted master charts which are reproduced by photolithography for the *Daily Weather Report*. The new plotter will also be used to prepare the hourly plotted charts for facsimile transmission to outstations where legibility of the received charts should be improved as a result of using better-quality master charts.

The COM equipment was used to prepare a 16 mm film of animated weather sequences for use at the Royal Society Silver Jubilee Exhibition in June.

Optimization of the system

The term 'optimization' covers many interrelated aspects: the balance of hardware components in the system, the efficiency of the operating system software, operating procedures, programming techniques and the matching of these to the system. The Branch collects, mostly by use of hardware and software monitors, information about the performance of the various components of the COSMOS system and its associated off-line equipment, and applies the information to improve the overall efficiency of both the equipment and the controlling software (operating systems). During 1977, much time was spent in improving and extending the capabilities of the various software monitors, which were then used to organize system data sets in the most efficient manner possible. Considerable effort was expended on discovering reasons for the poor terminal response under TSO and in attempts to improve it.

The programming techniques group, set up last year with members from all parts of the Office, examines standards for programming and documentation, and recommends programming techniques suitable for use in COSMOS. An analyst and a programmer are now available to continue preparation of a Programming Techniques Guide and to maintain an index of programs recommended for general use. Also, some of the newer methods of structured programming are being investigated. The Guide now contains chapters on design of disc and magnetic-tape data sets, documentation, Fortran compilers, Fortran program 'debugging' techniques and simple Job Control Language.

Considerable effort is devoted to the production of management and accounting information to enable user branches to control the use of the computing time allocated to them, and to provide information about the performance of the overall system and the changing demands made on it.

Data management for the First GARP Global Experiment

The First GARP Global Experiment (FGGE) is scheduled to start in December 1978 but the operational test phase started in December 1977. The Meteorological Office has agreed to establish a FGGE Area Sub-centre which will be responsible for the management of synoptic data received over the Global Telecommunication System from Africa, much of Europe and parts of the Middle East. During FGGE, and in the operational phase preceding it, special efforts will also be made to collect missing data from Africa by postal exchanges and to merge such data with those received via telecommunication channels. The detailed data-management plan was completed in the first quarter of the year and a 20-day operational trial took place in July, during which postal data were collected from Africa and merged with the telecommunication data.

Storage and preparation of data

In October the Redifon Seecheck processor-controlled keying installation (PCK) and the punched-card unit were brought together in a specially designed data-preparation area. The PCK installation is equipped with 19 key stations, each having a visual display screen connected to a NOVA 1200 computer with line-printer, disc and magnetic-tape facilities. Keyed data, totalling about 25 million characters per year, are written to magnetic tape for transfer to the COSMOS data banks; a direct computer-to-computer link is under consideration to facilitate these data transfers. Studies were started, in conjunction with the Climatological Services Branch, to determine whether additional keying of some data for verification purposes could be reduced as the quality-control of data by computer methods is improved.

The card-punching staff, who prepare over half a million cards each year for programmers in Headquarters, are also trained to operate PCK stations, and their co-location with PCK has rendered it easier to maintain essential services during periods of staff shortages.

Systems Development

Ever since its formation in 1971 the Systems Development Branch has been organized into two main sections, Data Archiving and New Systems. The first was devoted to the build-up and utilization of a central library comprising all classes of meteorological data in machinable form. The second was concerned with the design and application of new, usually mini-computer-based, systems to the functions of the Office, for which purpose a DEC PDP 11/40 mini-computer was installed in 1974.

In the latter section the amount of work has increased markedly as more projects have reached the implementation stage. There is now also a growing need to intensify efforts in the field of large scientific computers, on which much of our research and forecasting services depend. Thus, towards the end of the year, the Branch was expanded by the addition of a third section under the general heading Mathematical and Computing Services. This took over the running of the mini-computer laboratory but is primarily charged with studying and advising on advanced systems and techniques, especially in connection with computers of special design (for example, vector or array processors).

Archives of machinable data

The collection of meteorological data, both national and global, is a never-ending activity. The associated processing (conversion to machinable media, checking and storing in accessible formats) is similarly an on-going exercise and one of growing complexity. The observational networks are constantly changing and generally expanding whilst new, often automatic, means of monitoring atmospheric processes (for example, space satellites, weather radar, data loggers etc.) are being introduced. With the available effort it is difficult to keep up, even with current data; a large backlog of historical records still remain in their original forms (logbooks, autographic records and observational registers) and what have been converted so far are very variable in quality and in format.

Work has continued throughout the year in building up and checking the

central archives, using computer methods wherever possible. The main processing and storage medium is half-inch magnetic tape at a density of 1600 bits/inch and the total archives library is now approaching 5000 reels and still growing. However, the advent of the higher density (6250 bits/inch) tape system on COSMOS, to which many of the archives tapes are now being converted, should make it possible to ease the accommodation problem.

The special software, written to enable COSMOS users to access and display the data, is in constant use and new facilities are added as required. The annual published catalogue of this data library was considerably revised this year although hand methods were still employed in its production. However, experiments were carried out with a view, ultimately, to creating an on-line cataloguing, information retrieval and dissemination system, using the existing master directories containing information relevant to 800 or so climatological and 14 000 rainfall stations, past and present, in the United Kingdom, and some 10 000 synoptic stations world-wide.

The mini-computer laboratory

The PDP 11/40 mini-computer is linked directly to COSMOS and is equipped with a wide range of conventional units (discs, magnetic-tape drives, paper tape and card reader, terminals etc.), together with several special peripherals. These comprise an electrostatic printer/plotter, three non-standard tape drives for Philips, 3M and Epsylon cassettes, a graphics terminal, an auto-dial unit to provide access to remote devices (for example, automatic weather stations, several of which are already in the field) through the Post Office telephone system, analogue-to-digital and digital-to-analogue convertors (the latter to drive a facsimile recorder on-line) and a colour semi-graphics display. The entire system is operated on a real-time multiprogramming basis and runs throughout the 24 hours. Some of the work (such as the satellite data processing described below) requires to be run, unattended, at prescribed times of the day and night. To guard against the consequences of a power failure, a special clock was constructed which is automatically synchronized by the time-coded 60 kHz radio transmission broadcast from Rugby. This is coupled to a master program to control the rescheduling of tasks once the power is restored.

The laboratory is used by or on behalf of most Headquarters branches, partly on a semi-routine basis (e.g. for the production of satellite pictures or the handling of cassettes from field loggers), but mainly as a test bed to facilitate the design of new hardware and software systems.

Satellite data processing

Analogue signals from the NOAA-5 orbiting satellite are received at the Royal Aircraft Establishment station at Lasham and transmitted over land-line to Bracknell. Here they are used to produce on a facsimile recorder direct 'views' of the earth from space, both in the visible and infra-red ranges of the spectrum, for local use and for broadcasting to outstations on the satellite facsimile network. They are also relayed to the PDP 11/40 where they are digitized and written to disc, for processing and output. The main advantages of computer processing are that the pictures can be transformed to any map projection, with geographical outlines and latitude–longitude grids superimposed. Also, the contrast can be enhanced in various ways and views from successive orbits may be selected and combined into one picture. The result has been that the

Central Forecasting Office (CFO) has been able to obtain improved-quality satellite pictures on a 1:20 000 000 polar-stereographic map projection, as a composite of the information from several orbits covering most of their working-chart area.

Experiments were also carried out to produce pictures of improved (photographic) quality via the Calcomp microfilm plotter on COSMOS and to transmit pictures to outstations via facsimile directly from the computer. Any chosen section from the available projection can also be displayed on the colour semi-graphics terminal via an interactive program.

Apart from the actual operational value to CFO, all this work was in the context of designing a system dedicated to the processing and display of the much larger amounts of data from the new satellites (METEOSAT and TIROS-N) to meet the needs of all future users.

Library automation

The equipment (a PDP 11/34 computer, 2 visual display units (VDUs) and 2 magnetic discs) to automate the monthly editing and cataloguing of the publications received by the National Meteorological Library was delivered early in the year. Initially it was installed in the mini-computer laboratory for testing, familiarization by Library staff, and completion of the software (programs written by the Systems Development Branch). By the end of the year it had been transferred to its permanent location in the Library and had taken over the work of the old paper-tape editing machine. The VDU keyboard terminals are microprocessor-controlled devices, specially adapted to bibliographic work which requires upper- and lower-case characters and a variety of special symbols and editing features. The system is directly linked to COSMOS on which the printed output is produced via the more powerful facilities (microfilm plotting, fast line-printing) available there, and on which the bibliographic archive will be maintained. About six years' information derived from the old paper tapes has been edited and placed on disc. This will be updated month by month to form a growing machinable bibliography which, backed by special software and increased disc space, is expected to provide the basis for an on-line information retrieval and loans system.

Automation of outstation functions

It has been increasingly evident in recent years that to make adequate use of the increasing world supply of data and of centrally generated numerical forecast products from COSMOS, within the present limitations of staff and resources, faster telecommunications and more automated techniques of plotting and display will be needed at some of our Principal and Main Meteorological Offices.

All the main centres have rather similar functions, namely telecommunications (local message collection and editing), data processing (chart plotting and analysis) and weather forecasting, and all are very dependent on the reception of basic observations and forecast products from Bracknell. For these reasons it is feasible to think in terms of standard hardware and software modules, selecting from a range of options for particular centres. A representative amount of experimental work was successfully carried out on the PDP 11/40, involving the automation of synoptic plotting, contouring, retrieval from the COSMOS data banks etc., and a configuration capable of a comprehensive range of

functions (data acquisition, telecommunications, plotting, display) has been designed. A fully automated station would require two mini-computers and at least two each of discs, pen-and-ink plotters, printers and graphic VDUs, to ensure reliable operational working.

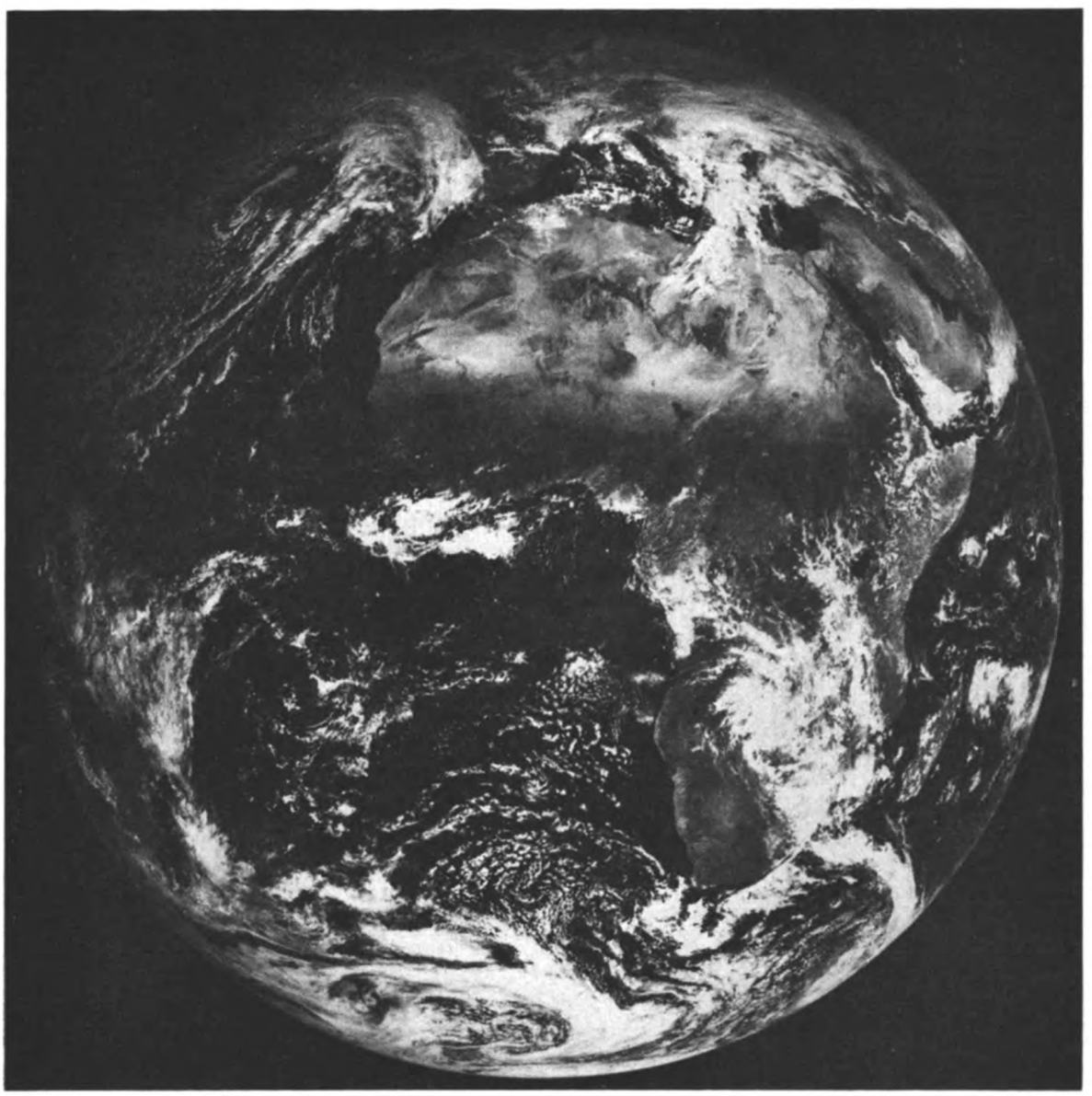
It is hoped to install automated systems at the Principal Forecasting Offices at London/Heathrow Airport and HQ Strike Command within the next two or three years. These are expected to be the forerunners of a more extensive system bringing in Main Meteorological Offices, Weather Centres, and ultimately subsidiary offices, automatic weather stations etc. This will require a redesigned telecommunication network within which the existing medium-speed (facsimile) and slow (telegraphic) lines would be more efficiently used. For example, it is much quicker to transmit contour charts in grid-point form rather than by analogue facsimile. Given the computer power and the plotting and display devices necessary to recreate them in contour form, the medium-speed lines could take over much of the facsimile and telegraphic traffic. The same lines could also be used by the major outstations to access the central data banks on COSMOS as and when required, a facility which has not previously been available.

Mathematical and computing services

Until the end of the year very little effort could be devoted to such services. What was done was of a miscellaneous nature, such as helping to prepare the Meteorological Office presentation at the Royal Society Silver Jubilee Exhibition, advice to other branches on their mini-computer requirements, developing a program to derive grid-point values from hand-drawn contours digitized by means of an automatic pencil-follower etc. Studies of mass-storage devices and of the fastest computers likely to be commercially available by the end of the present decade were continued. This was preparatory to setting up the new section, one of its important commitments being the specification of specialized computers to supplement and/or replace older components of the COSMOS system, on which the major part of the computing work of the Office is carried out. Another will be to continue running the mini-computer laboratory and to carry out further experimental work on the design of automated systems for general use either at Headquarters or at outstations. This will enable the New Systems section to concentrate on the actual procurement, testing and installation side of their work.

Meteorological Telecommunications

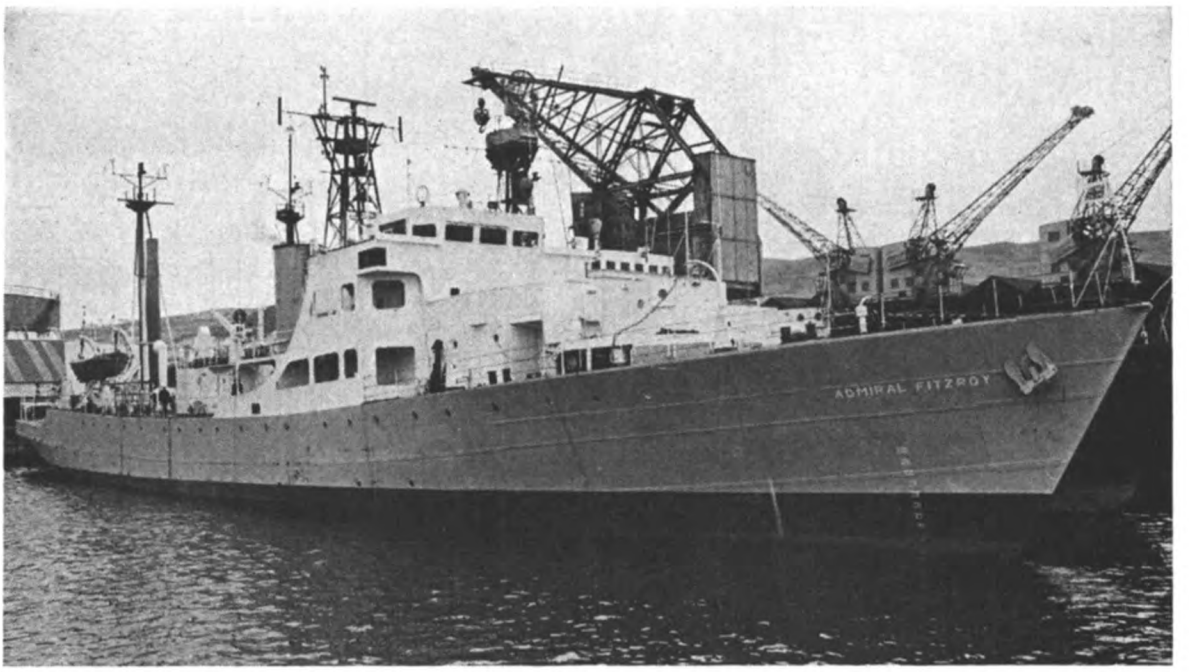
Telecommunications are indispensable to the provision of meteorological services. Observational information has to be collected and exchanged, and processed information (such as analyses and forecasts) has to be disseminated. These information transfers must be effected speedily, accurately and with a high degree of reliability. Speed and accuracy are more important than ever because computers are increasingly being used for handling information at all stages. Information must therefore be complete by the time the computer analyses are made, and both content and format must be of high integrity to allow automatic methods to be used effectively. The development of numerical forecasting models has led to a demand for complete hemispheric or even global coverage of data to enable forecasts to be produced for longer periods ahead.



An image produced by the European Space Agency's METEOSAT satellite between 1100 and 1125 GMT on 14 February 1978

This image, generated by the 'visible' channel of the radiometer, comprises 5000 lines each of 5000 values of the brightness. The spatial resolution of the raw image is about 2·5 km by 2·5 km at the sub-satellite point (i.e. where the Greenwich meridian crosses the equator). The resolution degrades towards the edge of the image; over southern England it is about 5 km by 3 km (see page 88).

PLATE II



The Ocean Weather Ship *Admiral FitzRoy* at the OWS Base, Greenock

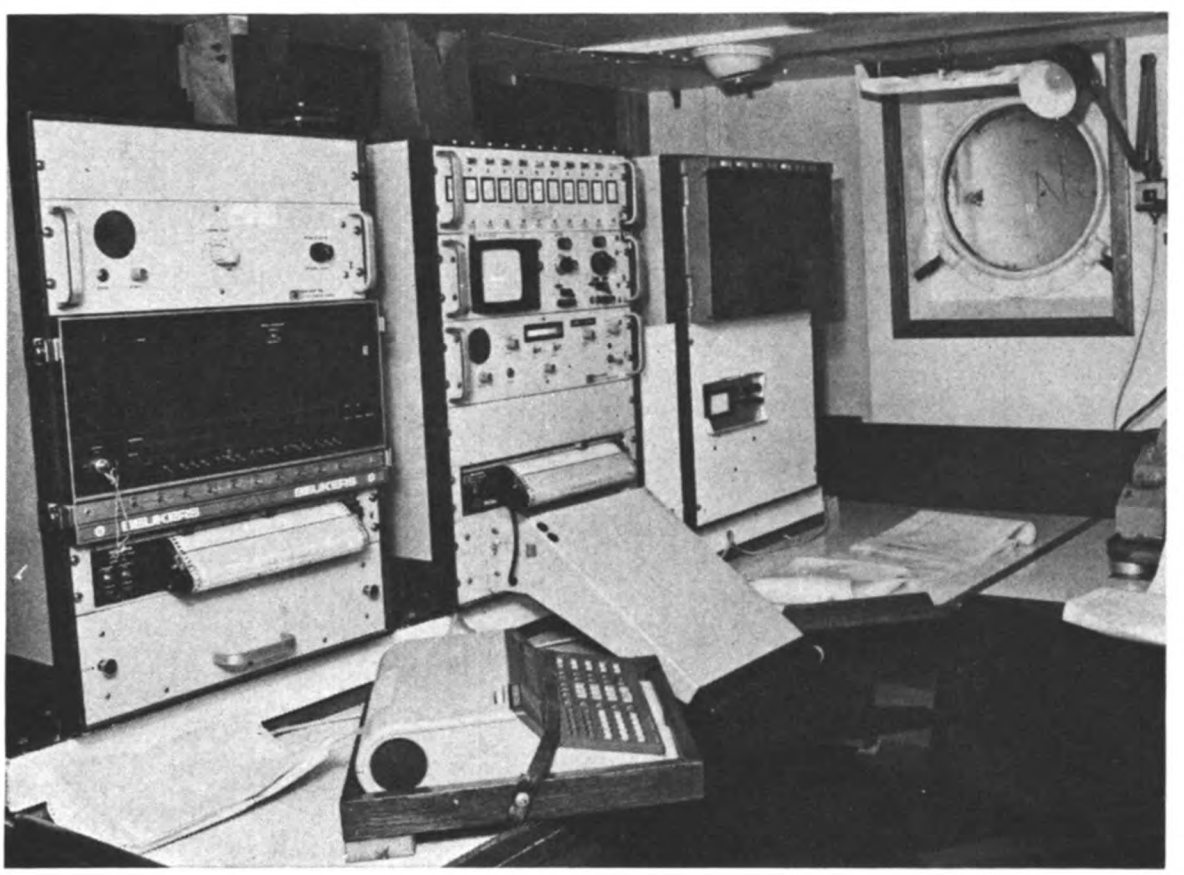
The ship had just arrived after completion of the refurbishing program at Manchester (see page 39).

The Ocean Weather Ship *Admiral FitzRoy* at sea on Station 'L'

Photograph taken on 28 June 1977 from an RAF Nimrod aircraft.

The refitted radio room on board the OWS *Admiral FitzRoy*

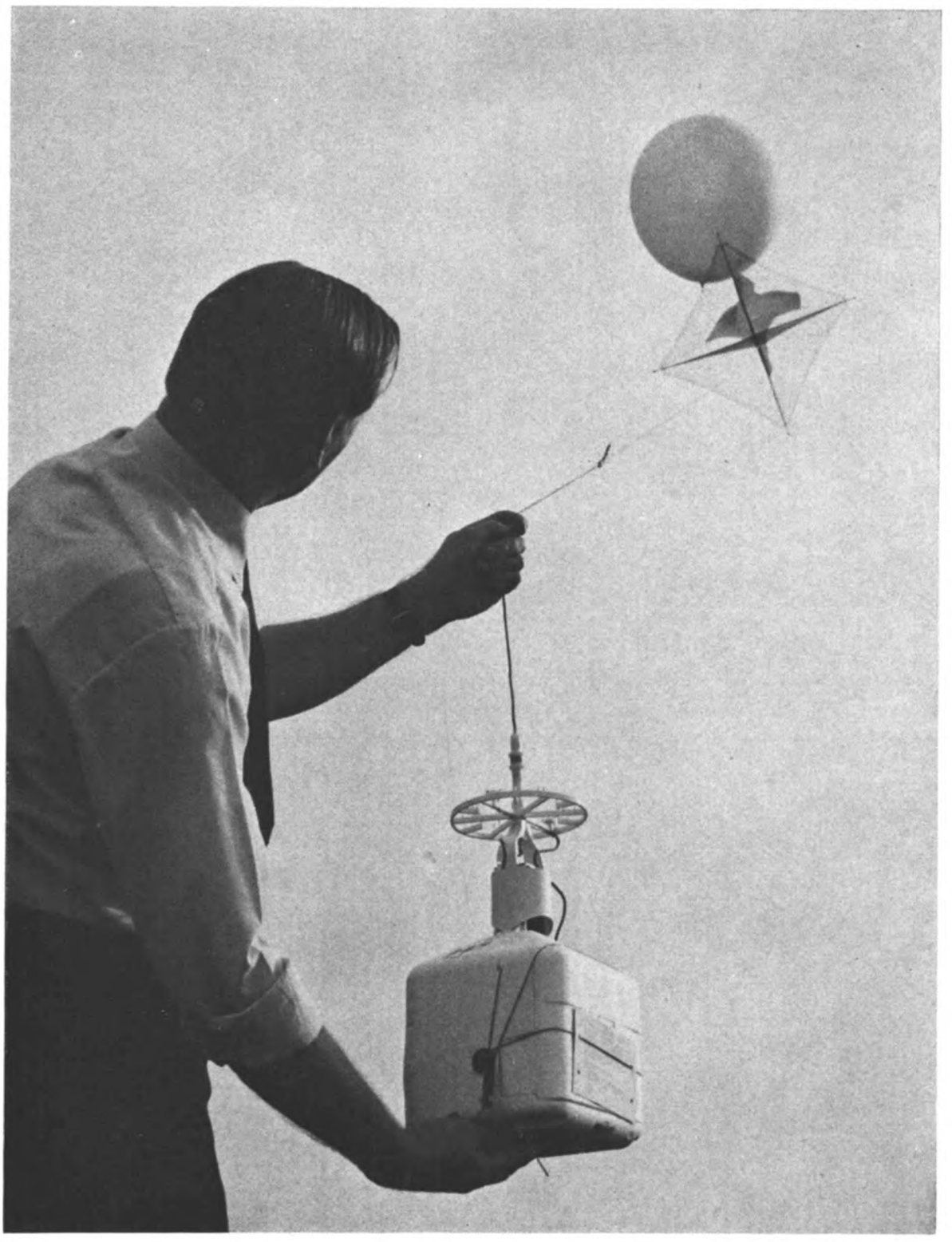
A range of modern HF and MF equipment is provided (see page 39).



Part of the meteorological office on board the OWS *Admiral FitzRoy*

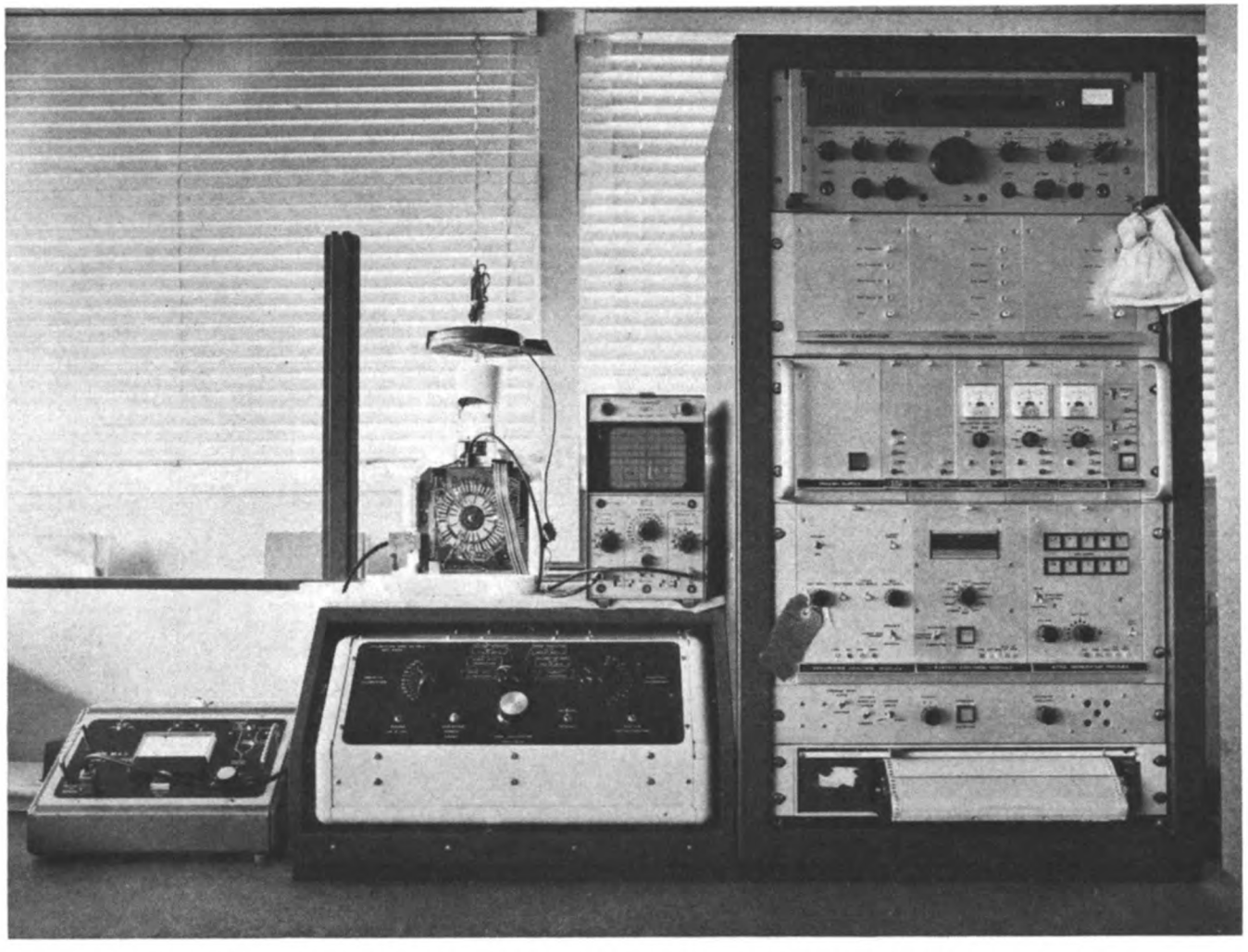
This shows the LOCATE equipment which is used in conjunction with a radiosonde for the determination of wind, temperature and humidity in the upper atmosphere (see page 39).

PLATE IV



A Mark 3 radiosonde about to be launched

Photograph taken at Beaufort Park, near Bracknell, during the course of the August 1977 trials of the overall system (see page 40).

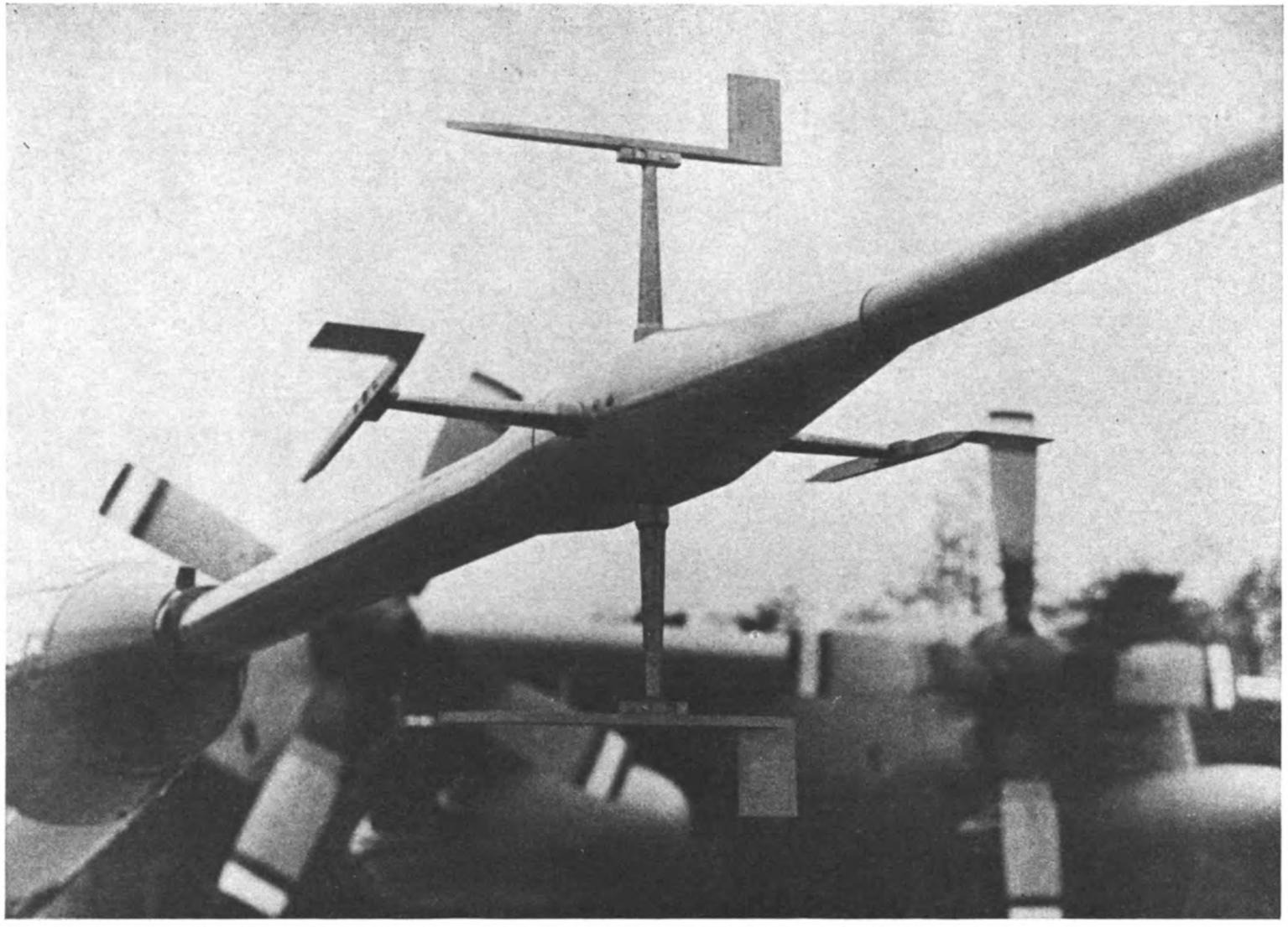


Part of the ground equipment used in the Mark 3 radiosonde system

A partly assembled sonde is shown near the centre of the picture (see page 40).

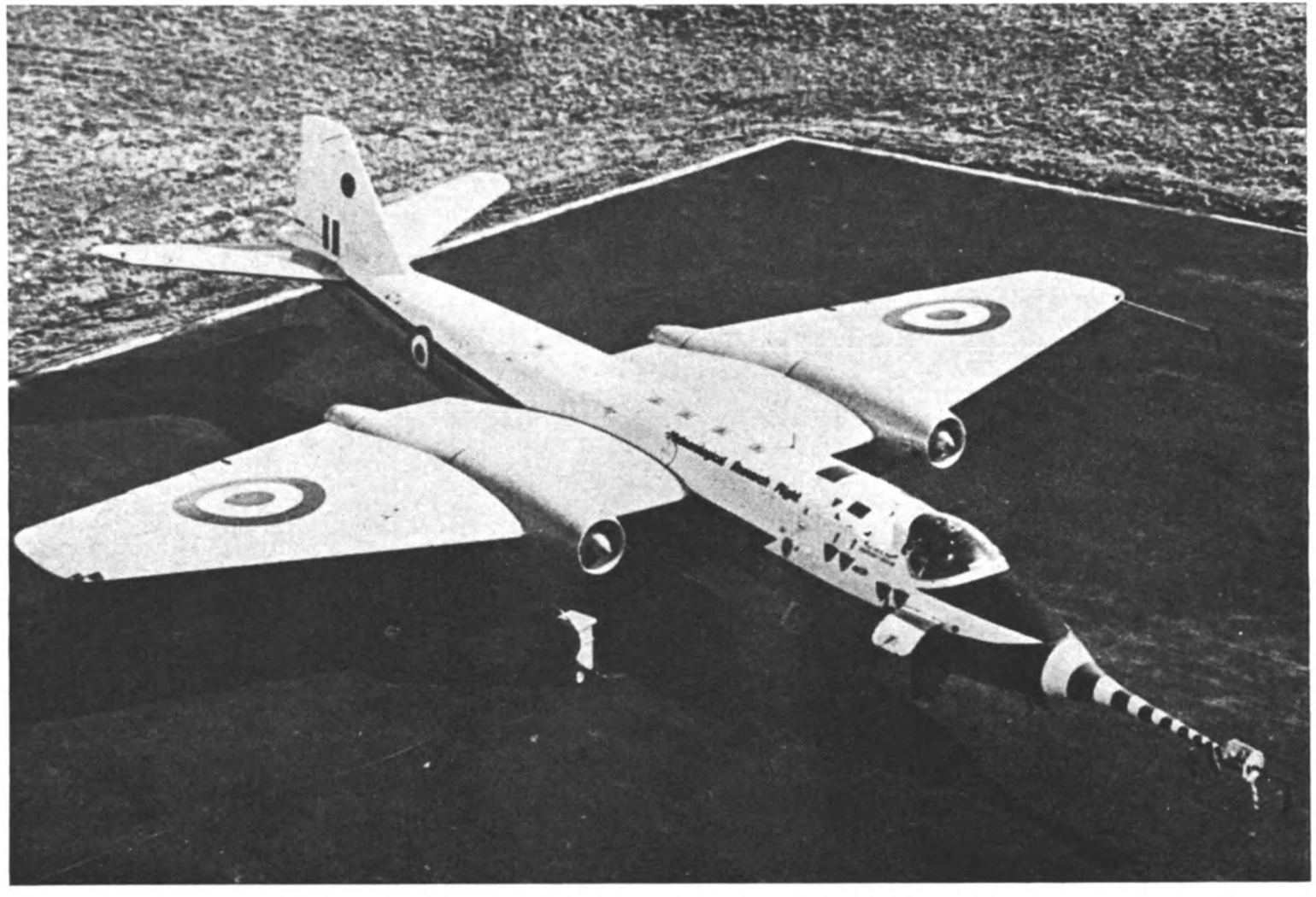
PLATE V

PLATE VI



Wind vanes of the Hercules aircraft of the Meteorological Research Flight

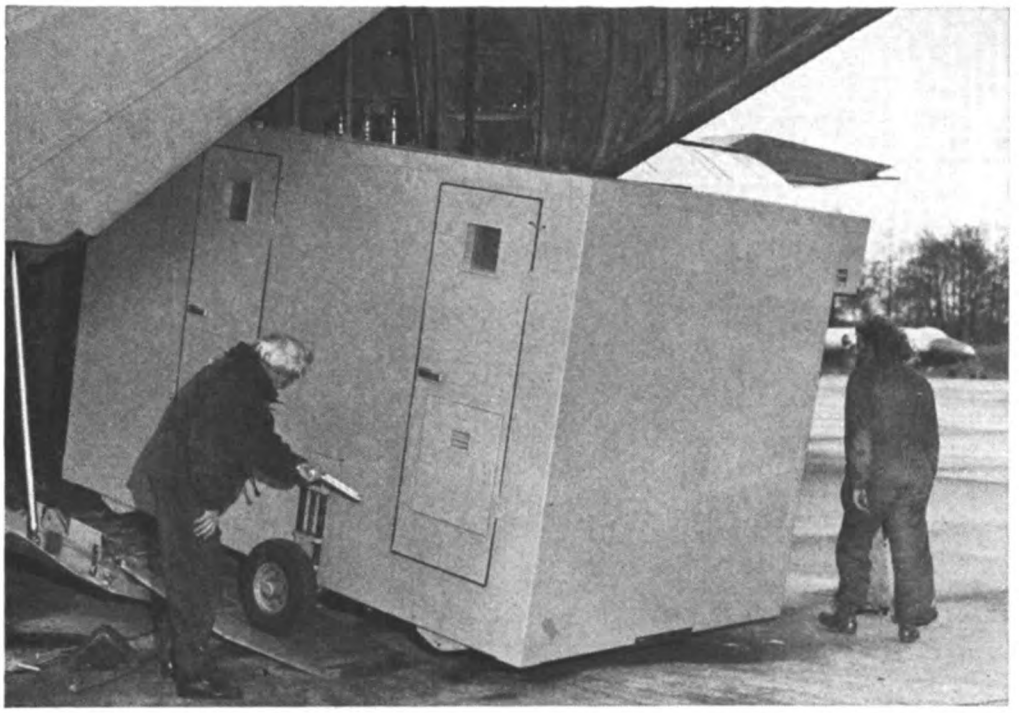
(See page 72)



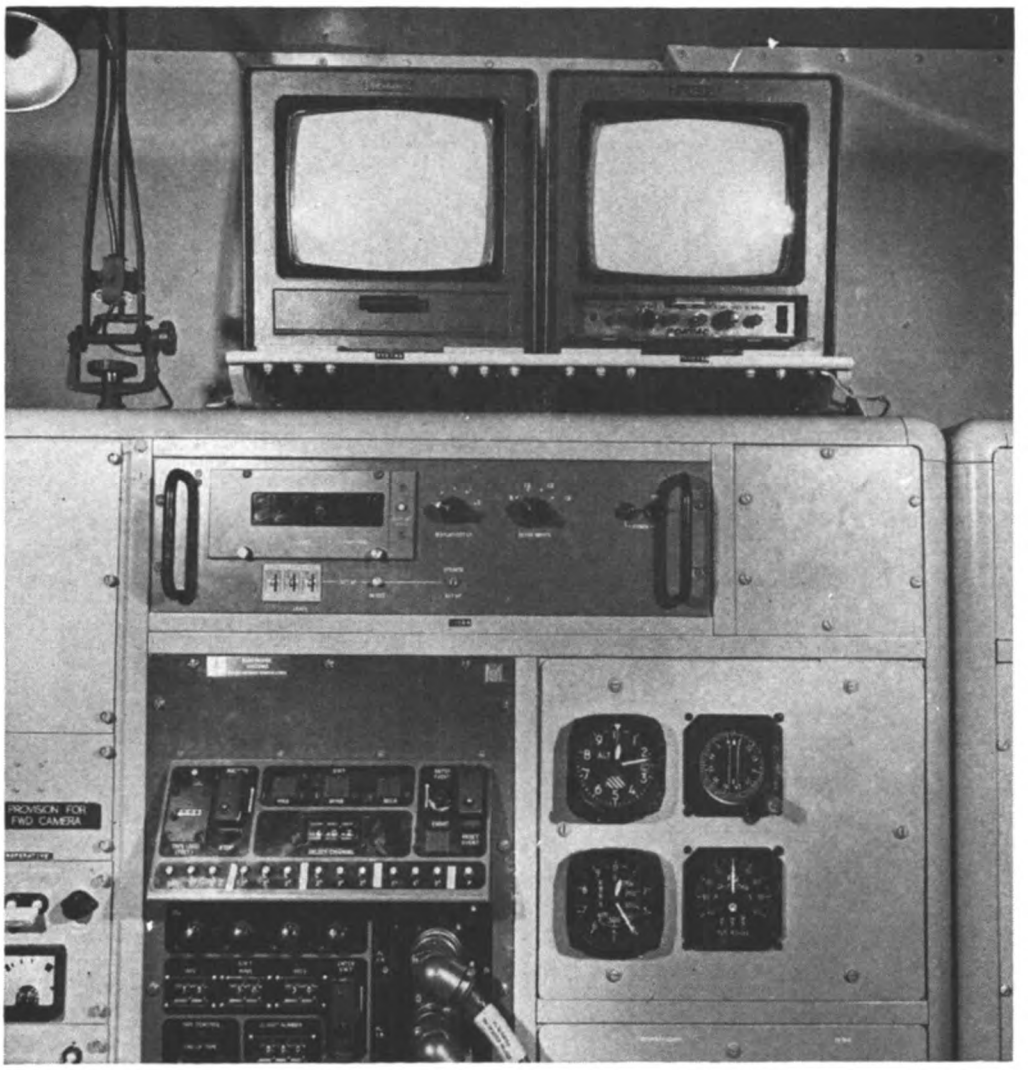
The Canberra aircraft of the Meteorological Research Flight

(See page 72)

PLATE VIII



The recorder/control van at the rear of the Hercules aircraft of the Meteorological Research Flight (see page 73)



The control panel for the data-recording system housed in the recorder/control van shown above

The main Meteorological Telecommunication Centre (Met TC) at Bracknell forms the main hub of an extensive land-line network of teleprinter and facsimile circuits, by means of which observational data and processed information are collected and distributed to support meteorological activities throughout the United Kingdom and for our Armed Forces in Europe. The Centre has a direct connection to the Lasham satellite ground station which receives pictorial and digital information from satellites; it is the Shore Collecting Centre for observations from the North Atlantic Ocean Station (NAOS) network.

Bracknell is a Regional Telecommunication Hub (RTH) of the WMO Global Telecommunication System (GTS) situated on the segment of the Main Trunk Circuit (MTC) which links Europe with North America. The Bracknell connections on the MTC are with Washington and Paris and these operate fully automatically at 2400 bits/second. A Main Regional Circuit between Bracknell and Offenbach operates in a similar fashion. The function of the MTC is to provide for the exchange of basic meteorological data and processed information, some of it in pictorial form, to support meteorological activities at the regional and global levels. The functions of the Bracknell RTH also include responsibility for the collection of observational data from Greenland, Iceland, Gibraltar, the Netherlands, the Republic of Ireland (as well as from the United Kingdom itself), ships and aircraft, and their onward transmission on the MTC and other circuits.

The Centre also operates two radio-facsimile broadcasts and one radio-teleprinter broadcast designed to provide reliable reception of both pictorial and alpha-numeric meteorological information within a radius of about 3000 km from Bracknell for the use of other meteorological services and ships at sea. Meteorological information to meet national needs of other countries is supplied by Bracknell over permanent leased circuits to the National Meteorological Centres (NMCs) at Brussels, Copenhagen, De Bilt, Dublin, Oslo and Reykjavik, and a system of land-lines distributes forecast products for civil aviation to centres in Denmark, France, Iceland, Ireland, Italy, the Netherlands, Norway, the Federal Republic of Germany, and Switzerland.

The Telecommunication Branch operates the Met TC in accordance with agreed national and international procedures for the collection and distribution of both basic and processed information on national, regional and global scales. It is involved in all the operational and technical aspects of the provision of services including forward planning, provision of land-lines, radio circuits and equipment, the communication aspects of the NAOS scheme, reception and dissemination of satellite data, the distribution of forecasts, gale warnings etc. to Post Office coastal radio stations and the BBC, and the provision of general communication support to the whole of the Meteorological Office. Many of the functions of the Met TC are now automated and, as a result, there has been a considerable reduction in the complement of staff in the Branch during the year, despite a steady increase in services provided. The automated system requires skilled and specialized support from the telecommunication staff, engineers and meteorologists who together constitute the Telecommunication Branch.

Four items are worthy of mention this year: there has continued to be a steady growth in the data provided by the Bracknell Automated Telecommunication Complex (AUTOCOM); the two refurbished UK ocean weather ships have come into service and the new radio installations on board have led

to improved communications with the shore station at Bracknell; there has been further enhancement of the receiving facilities at the Lasham satellite ground station which is operated in collaboration with the Royal Aircraft Establishment (RAE), Farnborough; and also a considerable extension of the facsimile network used to distribute the satellite products.

Bracknell Automated Telecommunication Complex

At the heart of the Bracknell operation is the AUTOCOM system. It controls operations on the MTC segments linking Bracknell, Washington and Paris which operate at 2400 bits/second; on the Main Regional Circuit with Offenbach at 2400 bits/second; on regional circuits with Oslo and De Bilt at 1200 bits/second; and on low-speed (50-baud) teleprinter links with Dublin, Brussels, Hilversum, Reykjavik, Rheindahlen, Cyprus, Malta, Gibraltar, 11 data-collecting centres, and many stations within the United Kingdom (the main national teleprinter broadcast serves more than 120 offices).

During the year the service to Reykjavik in Iceland was significantly improved by the installation there of an automated message system, through the WMO Voluntary Assistance Program. The Telecommunication Branch acted as the technical authority and an engineer visited Iceland. For the present, a combined service comprising facsimile charts and low-speed alphanumeric data is being provided to Iceland. The upgrading of the service to 1200 bits/second operation must await the provision of the Main Enhancement to AUTOCOM, to which reference is made below (page 57). The provision of a 2400 bits/second Main Regional Circuit with Brussels, already planned for 1979, will be provided from the same development. Modified services of data for Gibraltar and Cyprus were provided during the year to reflect the changing nature of the British presence in the Mediterranean area.

A vital function of AUTOCOM is to provide basic meteorological data to the main data-processing complex COSMOS, and to distribute COSMOS products. The link between the two systems is provided by means of an IBM System 7 mini-computer and during the year an improved version was brought into operational use. It includes a disc-storage capability so that data may be stored in System 7 for several hours, if necessary, to cover temporary operational difficulties in COSMOS, and so that service may be restored very quickly when required.

With the increasing use of automatic methods for the handling of meteorological information, any shortcomings in the flow, coverage and quality of data may be concealed until the end-products are examined. There are known to be deficiencies in the Global Observing System and in the Global Telecommunication System and a regular system of monitoring is essential. Important progress in this connection was made when the Extraordinary Session of the Commission for Basic Systems (CBS) in Geneva in November 1976 approved the 'plan for Monitoring the Operation of the World Weather Watch (WWW)'. The focal centre for the operation of this plan at Bracknell is the Data Monitoring and Quality Control section in the Met TC where meteorologists, working in close co-operation with telecommunication staff, monitor the flow of data through the Centre, with particular reference to the Bracknell zone of responsibility. Doubtful or misleading reports, discovered by staff in CFO or revealed by the quality-control routines in COSMOS (the data monitors have a visual display unit providing direct access to the synoptic data bank in COSMOS),

are referred back to the originating centres. In accordance with an agreement with the Meteorological Services of Iceland and Denmark, this task is now performed in respect of observations from Iceland and Greenland, as well as those from the United Kingdom. The data-monitoring service also provides regular checks on the completeness and timeliness of information received, and regular 'monitoring reports' are provided to the UK outfield and Gibraltar, to NMCs supplying data from Bracknell zone of responsibility, and to the telecommunication centres at Washington, Paris and Offenbach in accordance with the CBS monitoring plan. The Branch participated in several major monitoring exercises during the year, including a review of all 'global' bulletins received during a fifteen-day period in September, at the request of WMO.

During the year the contract for the additional twin system of Ferranti 700S message-switching computers, which will comprise the Main Enhancement to the existing auto-system, has made very disappointing progress. The probable date for delivery to Bracknell is now the spring of 1978, with operational availability delayed until around the end of that year. During 1977 the responsibility for maintaining the existing Marconi system was taken over from the Marconi Company by Meteorological Office technicians at a considerable financial saving. One of the most serious results of the delay in the provision of the Main Enhancement has been that the existing system has had to bear a significantly increased load of traffic, particularly analyses and forecasts in grid-point form, much of which should have been carried by the new system. This led to operational difficulties, and urgent steps, involving the employment of outside consultants, had to be taken late in the year to seek ways of reducing the effects of overloading the system.

Automatic Message Preparation Equipment

The need for data provided to the auto-system to be of very high quality has been evident from the beginning of the automation process. During the year a microprocessor-supported terminal, comprising a key-board and visual display unit, was used by the Radio Operator to supply observations from the NAOS system to AUTOCOM for distribution. This led to a significant saving in time and an increase in accuracy. A somewhat more ambitious project made significant progress during the year when a contract was placed for an automated data-input terminal specially adapted for use by the Meteorological Office. The terminal, to be known as AUTOPREP, will comprise a visual display unit and key-board, supported by storage and format-generating facilities, and will be installed not only at the Bracknell Met TC but also at a number of important meteorological offices in the UK. The terminal will include facilities for the compilation of meteorological bulletins, and also messages and forecasts of various kinds for transmission to consumers such as the BBC, public utilities and the Press; direct connection to the Post Office telex system will be incorporated in some cases. The introduction of AUTOPREP, which is expected to begin in 1979, will represent a significant extension of telecommunication automation to the Meteorological Office outfield in the UK.

Facsimile developments

The recorder replacement program continued during the year and all stations connected to the UK national land-line facsimile network (MOLFAX)

now have refurbished recorders designed for automatic operation at 120 or 240 r/min.

Tests of transmissions at 240 r/min were carried out, but it became apparent that the present network of lines is not capable, in some areas, of providing good-quality reception at this speed. Re-engineering of the network as a whole would not be justified at this time; but progressive improvement in some areas is being carried out and some further technical modifications to the recorders are being considered.

The tests carried out in 1976 between Washington, Bracknell, Paris and Offenbach, using Coded Digital Facsimile (CDF), established the general practicability of these procedures. The decoding was carried out by means of special programs in the System 7 mini-computer and the charts were recorded on a specially modified facsimile recorder. During 1977 a Ferranti Argus 700E computer was obtained so that work on the digitization of facsimile products could be continued with a view to operational implementation, both nationally and internationally. The benefits of digitized facsimile arise partly from the greater ease of handling products by computers, thus eliminating the delays and inevitable loss of quality in magnetic-tape relay operations, and partly from the fact that any future increase in data rates will proportionately reduce transmission times. Test exchanges at a data rate of 4800 bits/second took place during the year between Bracknell and Washington on the MTC. These confirmed that operation at that rate, using the present WMO procedures, including Error Detection and Correction (EDC), is possible when suitable computer equipment is available. The Telecommunication Branch continued to participate in international discussion about CDF and higher data rates on meteorological circuits, and the Assistant Director and a senior member of his staff attended the Geneva meeting of the CBS Working Group on the GTS in late November at which these and other technical matters were discussed.

Satellite data reception and distribution

The RAE satellite ground station at Lasham continued to provide Scanning Radiometer (SR) cloud images on a routine operational basis throughout the year from the US National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting satellites. Vertical Temperature Profile Radiometer (VTPR) data were received when required for use in the research branches. Early in the year the Lasham facilities were upgraded to provide for the acquisition of Very High Resolution Radiometer (VHRR) transmissions from the same series of satellites. Selected areas of the VHRR field of view are extracted for distribution to CFO and other recipients, and provision is made for temporary storage on magnetic tape in case other areas should be required.

The recorders used at the outstations are the Mufax TR4 series, modified by Hawker Siddeley Dynamics Ltd to present SR images in the visual and infra-red sections of the spectrum side by side and stretched laterally to improve image quality. The network of stations receiving satellite images (the network is known as SATFAX) was extended during the year to enable about 15 offices in various parts of the United Kingdom to receive both SR and sectorized VHRR images. The necessary technical work is in hand to provide for the reception at Lasham and subsequent distribution of information from the new series of US orbiting satellites (TIROS-N), and from the European Space Agency geostationary meteorological satellite (METEOSAT). By the end of

1977 experimental reception of images from METEOSAT (launched late in the year) had been carried out, and routine distribution of these is expected by about the spring of 1978. The TIROS-N series (which will provide SR images and a new advanced system of very-high-resolution images to be known as AVHRR) will not come into service, to succeed the NOAA series, before the summer of 1978. It is intended that SR, VHRR, AVHRR and METEOSAT images will all be distributed, as appropriate, via the SATFAX network, and the difficult questions of selection and scheduling are receiving detailed study. The meteorological offices at Gibraltar, Malta, Cyprus and Rheindahlen continued to receive satellite images, using local receiving facilities. Work is in hand to ensure that overseas stations will continue to be able to receive adequate satellite imagery for their operational use.

International and Planning

International co-operation is vital for both the day-to-day operation and the development of meteorological services, and the Meteorological Office has continued to play an important role through a number of international organizations. Foremost in meteorology is the World Meteorological Organization (WMO), an inter-governmental organization in which the Permanent Representatives of Member States are normally the Directors or Heads of their Meteorological Services. It is through WMO that almost all international co-operation in meteorology is conducted, procedures and standards are agreed, and networks of observing stations and telecommunications are planned and co-ordinated. In addition to its Congress and Executive Committee which meet in Geneva, the WMO has six Regional Associations which meet to discuss and deal with meteorological and hydrological problems on the continental rather than the global scale; the United Kingdom belongs to Regional Association VI (Europe) and also, because of continuing commitments to its few remaining island dependencies, to RA I (Africa). The United Kingdom is also represented on each of the eight Technical Commissions which deal with separate but world-wide aspects of the science of meteorology and its applications.

In September the Director-General, Dr B. J. Mason, was re-elected to the Executive Committee after a lapse of two years. In that interval the work of dealing with the mass of documents prepared for the Committee was much reduced. The recent addition of operational hydrology to the responsibilities of WMO has required some new working relationships, since work in the United Kingdom on operational hydrology is done largely by bodies other than the Meteorological Office. An inter-departmental committee for hydrology looks after co-ordination of international matters and its Chairman, the Director of the Central Water Planning Unit, is also Hydrological Adviser to the Director-General of the Meteorological Office as UK Permanent Representative with WMO.

The world-wide basic systems for observation, collection, dissemination, storage and retrieval of meteorological data comprise the World Weather Watch (WWW) program of WMO. The United Kingdom has added to the global network over the last ten years by the establishment of a number of stations making surface and upper-air observations, and continues to support them. The last of these stations, St Helena, is now operational and awaits only the completion of the telecommunication link to become a fully functional unit

in the Global Observing System of WWW. This station, set on a small island in the South Atlantic Ocean, is manned by officers from the United Kingdom, who do a tour of 18 months, and observing staff recruited and trained locally. Shipping presented a problem during the year with the withdrawal of ships of the Union-Castle line. However, a joint venture by the Government of St Helena and a private shipping company has begun to operate a resumed regular service; there is no airport on the island. The WWW upper-air station at Mahé in the Seychelles, now operated by the Seychelles Meteorological Department, has two posts filled by secondment from the UK Meteorological Office. Suitable training courses to equip locally recruited staff to take over these posts have been worked out and training is expected to begin in 1978. Seychelles became a full Member of WMO during 1977. The Technical Officer post at the upper-air station on Tarawa (Gilbert Islands) is likely to be filled by a Gilbertese on completion of his course of training in New Zealand. Proposals have been made for the filling by local staff of two posts (at present filled by secondment from the Meteorological Office) in the New Hebrides, but there are no plans for changes in the immediate future. Following the retirement of the Meteorologist-in-Charge, a successor has been appointed and seconded for two years from the Office. The observer post at the Royal Society Research Station on the atoll of Aldabra continues to be filled by volunteers. Most of these posts are in isolated spots and some particular qualities such as resourcefulness and determination are called for; volunteers continue to come forward.

The WMO Agreement on North Atlantic Ocean Stations (NAOS) continued in operation, maintaining the network of weather ships which make surface and upper-air observations in the North Atlantic. The second meeting of the NAOS Board sought wider financial support from Member States to ensure the continuation of an observing system which is of value to much of North America and Europe. The observations from all the ships are collected and disseminated through the Telecommunication Centre at Bracknell.

The WMO Voluntary Assistance Program (VAP) was established so that less-developed countries might be helped in carrying out their responsibilities under WWW. The Office has continued to give its support. During 1977, projects were completed in Belize (radio-facsimile equipment) and Iceland (telecommunications). In Botswana all but one of a number of single-side-band transceivers were installed by the WMO Telecommunication Expert in Africa; he spent some weeks with a team of Botswana helpers travelling around the mainly desert region in two motor transports, in which they lived in primitive and often dangerous conditions. A radar wind-finding station at Kasama in Zambia is expected to be completed shortly and another has been offered for use at Mongu. Two other radar wind-finding stations are being provided to Mauritius for use on two Indian Ocean islands. Short-term Fellowships for training of staff from developing countries, for the installation and operation of equipment provided under VAP, were introduced this year and the first students have completed their courses in this country.

In March a cable from WMO asked for assistance for Romania, to replace meteorological equipment lost in the severe earthquake there. We were happy to be able to respond quickly by supplying equipment held in store; it was handed over to Romanian Embassy staff at London Airport and flown direct to Bucharest. A letter expressing warm appreciation was subsequently received from the Director of the Institute of Meteorology and Hydrology of Romania.

Mr Palamoudian, the WMO Telecommunication Expert for Africa, visited the Office in July for discussions about our VAP projects in Africa. Mr Zavos, Chief of the VAP Branch of the United States National Oceanic and Atmospheric Administration (NOAA), paid a visit in October to discuss, in particular, the possibility of co-operation in technical matters in the field. Mr Adejokun and Mr Ewulu, meteorologists from Nigeria, arrived in April for a few days of discussion, chiefly on telecommunications in Nigeria. The United Kingdom has an interest there in that some of the equipment for the Regional Telecommunication Hub at Kano was supplied under VAP, and the eventual access for St Helena to the Global Telecommunication System will be via a point-to-point link with Kano. Such personal contacts are of great value; the hope is that they can be extended to provide a closer working relationship between the personnel involved in VAP projects in the field.

The selection of VAP projects for implementation by the United Kingdom has been made primarily on scientific and technical grounds, in keeping with the traditional role of meteorologists and in line with priorities set out by WMO. The Assistant Director (International and Planning) represented UK at a meeting in June of the Executive Committee Panel on VAP. The Panel reviews policy and guidelines for the implementation of VAP (Equipment Services) and controls the use of the VAP Fund, to which the United Kingdom is a contributor. Within the Office there is a continuing reappraisal of policy and a questioning of the assumptions on which that policy is based, with the intention of ensuring that money spent on supplying equipment and services is used to the best advantage.

Preparation for the First GARP Global Experiment (FGGE) has continued throughout the year, particularly with arrangements for the making and collection of special observations and the dissemination and handling of data. The United Kingdom has agreed to provide the services of one or two experts to act as travelling advisers whose task it will be to help to bring up the operational standard of the WWW to the level required to ensure the success of FGGE. The European Space Agency's geostationary meteorological satellite METEOSAT was launched in November to be one of a chain around the world during FGGE.

The meteorological aspects of other international activities are dealt with through such organizations as the International Civil Aviation Organization (ICAO) and the North Atlantic Treaty Organization (NATO). The International Council of Scientific Unions (ICSU), in which scientists participate as individuals rather than as representatives of scientific bodies, is responsible, together with WMO, for the Global Atmospheric Research Program.

The European Centre for Medium-range Weather Forecasts (ECMWF) works in co-operation with WMO. The development of the Centre passed an important stage early in the year when the ECMWF Council reached decisions on the very powerful computer system to be acquired. The permanent buildings for the Centre are under construction at Shinfield Park, near Reading, and should be ready for occupation late in 1978. Office experts contributed to the study, not only of the computer requirements of the Centre, but also of the future telecommunication system by which Member States will get the computer's products. Mr F. H. Bushby, Deputy Director (Forecasting Services) became a member of the Centre's Scientific Advisory Committee in place of Mr J. S. Sawyer, formerly Director of Research in the Office.

Mr D. G. Harley, Assistant Director (International and Planning) attended the Antarctic Treaty Consultative Meeting in September to assist a working group on Antarctic telecommunications. British interests in the Antarctic are the concern of the British Antarctic Survey (BAS). The Meteorological Office was able to provide BAS with some financial assistance to replace old unserviceable radar wind-finding equipment at Halley Bay, a WWW station which should be fully operational again in time to contribute to FGGE.

One consequence of the limited shipping services to St Helena is that energy conservation and the tapping of local sources of energy have become increasingly important there. As a contribution to a preliminary exercise in assessing the practicability of extracting energy from the wind, the Meteorological Office has made available to the St Helena Government anemometers to be exposed in suitable locations.

In February the Program Review Committee (PRC) was established in the Meteorological Office to review the progress of the activities of the Office and decide on the direction and distribution of effort each year and for up to ten years ahead. It supersedes the Research Policy and Requirements Committee. The members of the PRC are the Directors, Deputy Directors and the Secretary of the Office, with the Director-General as Chairman. The Assistant Director (International and Planning) is Secretary to the Committee. It expects to meet three or four times a year. Work is in hand to compile a complete list of functions and activity cost headings which, together with a new and extended cost accounting system, should improve financial control over all the work of the Office and facilitate a comprehensive planning system for all activities, taking due account both of requirements and resources.

G. A. CORBY
Director of Services

STATISTICS OF THE SERVICES DIRECTORATE

The quantitative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I—NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1977

	Within UK	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	6	4
Subsidiary offices associated with the RAF	27	4
Observing offices associated with the RAF	5	1
Principal Forecasting Offices associated with civil aviation ...	1	—
Main Meteorological Offices associated with civil aviation ...	3	—
Subsidiary offices associated with civil aviation	10	—
Observing offices associated with civil aviation	8	—
Upper-air observing offices	8	2
Weather Centres	6	—
CRDF offices...	5	2
Port Meteorological Offices...	6	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	4	—
Other offices	23*	3

*Four of these stations are administered by DR Met O.

Notes

A Principal Forecasting Office meets the needs of aircraft flying over long distances and operates throughout the 24 hours.

A Main Meteorological Office operates throughout the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

An upper-air observing office may be located with an office of another type if this is convenient.

Weather Centres are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II—OCEAN WEATHER SHIPS

To meet the United Kingdom obligations under the WMO Agreement for the Joint Financing of the North Atlantic Ocean Stations (NAOS), the Office operated two ocean weather ships. These were employed to man ocean station 'L' (57°00'N, 20°00'W), one of the four stations of the network, each ship spending an average of 24 days on station each voyage. The station was manned for a total of 340 days in 1977 and the two ships were on passage for 69·5 days. Two ships from France, one from the Netherlands, one jointly operated by Norway and Sweden and five ships from the USSR served at the other three stations.

TABLE III—MERCHANT NAVY SHIPS

A total of about 7370 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization. Most of them, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected ships'; those which report at the same times daily, but in a less complete form, are known as 'supplementary ships'. A number of coasting vessels, lightships, distant-water trawlers and 'auxiliary ships' also make and transmit meteorological observations.

On 31 December 1977 the numbers of British ships reporting were:

Selected ships	515
Supplementary ships (including 8 trawlers)	38
Coasting vessels	57
Lightships (including 1 light-tower)	13
Trawlers	7
Auxiliary ships	6
Total	636

The British Voluntary Observing Fleet includes ships of many shipping companies, and the numbers on the various routes are as follows:

UK to Australasia	49
UK to Far East	59
UK to Persian Gulf	38
UK to South Africa	34
UK to West Indies	22
UK to Atlantic coast of North America	53
UK to Pacific coast of North America	14
UK to South America	16
UK to European ports	40
UK to Falkland Islands and Antarctica	2
UK to distant-water fishing grounds	15
World-wide tramping	173

During two typical five-day periods, one in June and the other in November, the average daily numbers of reports from ships received at Bracknell were as follows:

	Reports *June*	Reports *November*
Direct reception from:		
British ships in eastern North Atlantic	92	115
Foreign ships in eastern North Atlantic	100	89
British ships in North Sea	29	27
Foreign ships in North Sea	8	12
Ships in other waters	7	17
Total	236	260
Reception via other countries:*		
Ships in eastern North Atlantic	455	503
Ships in western North Atlantic	299	335
Ships in Mediterranean	59	60
Ships in North Sea	98	87
Ships in Arctic Ocean	66	53
Ships in North Pacific	749	821
Ships in other waters	313	281
Total	2039	2140

*Via the Global Telecommunication System.

TABLE IV—CLASSIFICATION OF STATIONS SUPPLYING CLIMATOLOGICAL INFORMATION

For climatological purposes, data are obtained not only from official sources but also from very many stations which are not part of the Meteorological Office. The following table shows the distribution on 31 December 1977 of stations which supply climatological information. The areas and titles of the districts are those used in the *Monthly Weather Report.*

	Stations Supplying Returns				Stations Supplying Autographic Records			
	Observatories	*Synoptic*	*Agrometeorological*	*Climatological*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	11	2	31	310	25	21	14
Scotland, east	0	10	7	62	569	45	23	12
Scotland, west	1	13	1	49	512	25	22	18
England, east and north-east ...	0	10	8	26	502	32	18	14
East Anglia	0	11	14	21	464	28	8	12
Midland Counties	0	10	14	42	1244	42	18	14
England, south-east and central southern	1	15	17	46	793	58	30	23
England, south-west	0	16	7	31	627	38	7	12
England, north-west	0	5	3	18	515	18	19	12
Isle of Man	0	2	0	1	21	3	1	3
Wales, North	0	3	3	16	281	12	2	4
Wales, South	0	8	7	18	350	20	6	6
Channel Islands	0	2	0	3	21	6	0	2
Northern Ireland	0	6	7	45	260	26	50	9
Total	3	122	90	409	6469	378	225	155

*Includes stations in earlier columns.

TABLE V—HEIGHTS REACHED IN UPPER-AIR ASCENTS

The following table shows the number of upper-air ascents giving observations of (a) temperature' pressure and humidity and (b) wind, which have reached specified heights, and the height performance of the largest balloons.

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb (≈ *16 km*)	*50 mb* (≈ *20 km*)	*30 mb* (≈ *24 km*)	*10 mb* (≈ *30 km*)	*10 mb* (≈ *30 km*)
(a) Temperature, pressure, humidity:						
Eight stations in the UK ...	5820	95·6	84·6	68·9	23·9	61·7
Two stations overseas	1457	96·1	89·6	80·7	47·4	64·8
One Ocean Weather Station (two ships)	674	96·0	72·6	68·2	9·3	—
(b) Wind:						
Eight stations in the UK ...	11 630	91·6	69·8	40·0	12·3	63·3
Two stations overseas	2918	94·5	81·5	51·5	26·5	71·3
One Ocean Weather Station (two ships)	1339	91·5	73·6	46·4	3·7	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF Network:

In 1977 ... ... 49 532

TABLE VII—METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchanges of meteorological data which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. The coded messages comprise mainly groups of five figures and there may be from 5 to around 300 such groups in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic (mainly coded messages and information in pictorial format) through the Meteorological Office Telecommunication Centre, Bracknell, for one typical day (24 hours) taken in November 1977 and, for comparison, some corresponding figures are given for one day near the end of 1976.

	In	Out	Total	Total in 1976
Coded messages:		*number of groups in one day*		
Land-line teleprinter and data transmission	644 232	2 478 252	3 122 484	2 679 421
Radio transmission	13 626	185 768	199 394	214 180
Facsimile charts (pictorial format):		*number of charts in one day*		
Land-line transmission... ...	100	994	1094	1163
Radio transmission	89	120	209	147

Continued improvements in land-line reception have reduced duplication and led to a modest decrease in the number of groups received; but the services provided by the Telecommunication Centre at Bracknell continue to increase and diversify, and the total number of groups handled (in and out) shows a considerable increase over the previous year.

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are described in *Met O Leaflet* No. 1 (1977). The numbers receiving such specialized services were as follows:

	Year	Number of customers	Year	Number of customers
Dry-spell notifications (a summer service primarily for farmers)	1976	135	1977	137
Week-end temperature forecasts (a winter service primarily for industrialists) ..	1976/77	65	1977/78	68
Winter road-danger warnings (primarily for local authorities)	1976/77	300	1977/78	285

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office, acting as a Regional Meteorological Centre of the World Weather Watch, is mainly concerned with the analysis of the weather situation and with the issue of forecast charts for the guidance of other offices, including the two Principal Forecasting Offices which serve civil aviation from London/Heathrow Airport and military aviation from the Headquarters of RAF Strike Command. The Central Forecasting Office also has a commitment to civil aviation in the provision of wind and temperature charts for use with the significant weather charts produced by the Principal Forecasting Office at Heathrow and for the transmission of grid-point data direct to the British Airways BOADICEA and APOLLO computers at Heathrow and Prestwick respectively and to the Dutch and Belgian Meteorological Services.

The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1976 and 1977. These do not include warnings and routine general forecasts.

	1976	1977
Number of meteorological briefings for		
aviation in the UK	363 467	356 818
aviation at overseas stations	37 766	41 473
Number of aviation forecasts issued for		
aviation in the UK	1 852 416	1 916 359
aviation at overseas stations	304 223	259 755

TABLE X—NON-AVIATION ENQUIRIES

Non-aviation enquiries are handled by six Weather Centres in London, Manchester, Glasgow, Southampton, Newcastle and Nottingham whose function is to meet the needs of the general public for forecasts for special purposes. Many other forecasting offices, established primarily to meet the needs of aviation, also answer requests for forecasts and other weather information from the general public, the Press, public corporations, commercial firms etc. These enquiries, most of which refer to current or future weather, are listed below according to the purpose of the enquiry.

	1976	1977
Total number of non-aviation enquiries	1 865 050	1 973 002
Percentage relating to:		
agriculture	10·7	13·1
building	4·7	4·7
commerce, industry	5·1	4·8
holidays	18·8	19·1
marine matters	14·7	14·6
Press	10·8	10·0
public utilities	9·4	8·7
road transport	9·5	7·2
other known purposes	6·3	6·7
unknown purposes	10·0	11·1

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC and to most independent broadcasting companies for inclusion in their programs at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1977.

	Dense fog	Moderate or heavy snow	Heavy rain	Glazed frost and icy roads	Severe inland gales
Edinburgh and south-east Scotland ...	—	—	3	—	5
Glasgow and south-west Scotland	5	—	3	—	5
Belfast and Northern Ireland	1	1	—	1	5
Industrial north-east England	—	—	2	2	6
Industrial Lancashire and Merseyside ...	1	1	—	2	5
Industrial Midlands	—	2	6	—	4
Bristol and Bath	—	—	2	—	4
South Wales	1	1	5	—	7
London and south-east England	—	2	8	—	5
Plymouth and south-west England... ...	—	—	3	—	5
Yorkshire	—	—	—	—	5
Southampton and Portsmouth	—	—	3	—	4
Total	8	7	35	5	60

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

Information Service Centre	Forecast area	Number of calls 1976	1977
Bedford	40 miles radius of Bedford	238 481	285 003
Belfast	Belfast	260 533	306 101
Birmingham	Birmingham	821 772	908 843
Bishop's Stortford	40 miles radius of Bedford	77 234	92 581

Information Service Centre	Forecast area	Number of calls 1976	1977
Blackburn	Lancashire, Cheshire, Greater Manchester and Merseyside	220 601	257 134
Blackpool	Lancashire, Cheshire, Greater Manchester and Merseyside	153 492	170 059
Bournemouth	South Hampshire	271 982	330 008
Bradford	Leeds, Bradford, Huddersfield	104 732	138 812
Brighton and Hove	Sussex coast	461 872	587 268
Bristol	Bristol	542 056	695 439
Cardiff	Cardiff	520 489	421 433
Canterbury	Kent coast	251 064	307 039
Chelmsford	Essex coast	114 032	165 865
Cheltenham	South-west Midlands	102 748	127 407
Chester	Chester and North Wales coast	150 282	145 404
Colchester	Essex coast	184 937	234 213
Colwyn Bay	Chester and North Wales coast	78 156	88 650
Coventry	Birmingham	193 377	310 949
Derby	Nottinghamshire, Derbyshire, Leicestershire	133 436	150 385
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	43 384	47 156
Edinburgh	Edinburgh	387 826	361 492
Exeter	Devon and Cornwall	181 672	245 188
Glasgow	Glasgow	555 830	612 114
Gloucester	South-west Midlands	165 836	208 969
Grimsby	North Lincolnshire and Retford area	53 847	53 783
Guildford	London	118 019	150 394
Hastings	Sussex coast	23 012	59 185
Hereford	South-west Midlands	79 912	90 094
High Wycombe	Thames Valley	87 147	118 177
Huddersfield	Leeds, Bradford, Huddersfield	38 599	59 060
Ipswich	Norfolk and Suffolk	171 320	191 585
Leeds	Leeds, Bradford, Huddersfield	351 055	390 761
Leicester	Nottinghamshire, Derbyshire, Leicestershire	191 415	256 943
Lincoln	North Lincolnshire and Retford area	118 369	136 045
Liverpool	Lancashire, Cheshire, Greater Manchester and Merseyside	324 976	355 861
Liverpool	Chester and North Wales coast	39 151	
London	London	2 934 872	3 216 033
London	Essex coast	123 888	159 315
London	Kent coast	141 765	186 819
London	Sussex coast	277 298	339 615
London	Thames Valley	164 097	192 662
London	40 miles radius of Bedford	93 430	120 779
Luton	40 miles radius of Bedford	163 517	203 270
Manchester	Lancashire, Cheshire, Greater Manchester and Merseyside	551 068	696 905
Manchester	Chester and North Wales coast	68 916	
Medway	Kent coast	154 797	236 419
Middlesbrough	North-east England	168 793	176 044
Newcastle	North-east England	478 984	412 266
Newport, Gwent	Chepstow, Castleton, Tredegar	—	72 262
Northampton	40 miles radius of Bedford	13 743	29 567
Norwich	Norfolk and Suffolk	248 917	302 499
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	428 925	468 769
Oxford	Thames Valley	225 081	273 681
Peterborough	40 miles radius of Bedford	89 332	97 674
Plymouth	Devon and Cornwall	320 936	494 229
Portsmouth	South Hampshire	363 578	425 738
Reading	Thames Valley	277 256	349 995
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	286 870	400 987
Southampton	South Hampshire	397 526	546 293
Southend	Essex coast	197 768	259 263
Southport	Lancashire, Cheshire, Greater Manchester and Merseyside	48 182	51 643
Swindon	Bristol	38 934	44 268
Torquay	Devon and Cornwall	111 381	137 322
Tunbridge Wells	London	68 183	86 897
Total		16 205 683	19 040 617

TABLE XIII—CLIMATOLOGICAL ENQUIRIES

Met O 3, Met O 8, Edinburgh and Belfast receive a number of enquiries relating to past weather, to climatology and to the application of meteorological data to agriculture. The following figures give the total number of enquiries and the percentages of this number in various categories.

	1976	1977
Total number of climatological enquiries	26 126	28 986
Percentages relating to:		
agriculture (farming, forestry, market gardening)		9·0
building and design (including siting)		26·3
commerce (sales, marketing, advertising)		2·8
drainage		2·6
education and literature		3·7
flooding		0·3
heating and ventilation		4·7
industrial and manufacturing activities		4·1
law (damage, accident, insurance)		12·7
medical and health		0·9
Press and information centres		1·8
resea·ch		7·9
sports, hobbies, holidays		0·9
transport and communications		2·4
water supplies		8·1
miscellaneous (purpose known)		6·2
miscellaneous (purpose unknown)		5·6

TABLE XIV—DATA PROCESSING

(a) Punched-card installation

Number of cards punched by the Meteorological Office installation	452 975
Number of cards punched elsewhere on behalf of the Meteorological Office ...	181 129

(b) Processor-controlled keying system

The processor-controlled keying (PCK) system was used for data preparation during 1631 hours.

(c) Computer installations

(1) The 360/195 computer was used for computing during 8587 hours.
(2) The 370/158 computer was used for computing during 8606 hours.

TABLE XV—INSTRUMENT TESTING, CALIBRATION AND ACCEPTANCE

General meteorological instruments:	
Wind measuring	561
Pressure measuring	1475
Humidity measuring	156
Precipitation measuring	500
Radiation measuring	242
Sunshine recording	58
Temperature measuring	2779
Miscellaneous	3155
Electrical/electronic instruments and systems	1103
Electrical/electronic components	464
Balloons	42 620
Radar reflectors	33 800
Radiosonde parachutes	25 000
Mk 2b radiosondes calibrated	7880
Mk 2b radiosonde recoveries received	1431
Mk 3 radiosonde component parts	88 693
Total	209 917

DIRECTORATE OF RESEARCH

Special Topic—The Meteorological Research Flight

Introduction

The Meteorological Research Flight (MRF) of the Meteorological Office was established to conduct atmospheric research from aircraft. Its predecessor was set up at Boscombe Down in 1942, equipped with Spitfire and Boston aircraft, to investigate meteorological problems associated with wartime operation of aircraft. In 1946 the Flight was moved to the Royal Aircraft Establishment (RAE), Farnborough, where it has remained ever since, and was then formally recognized as the Meteorological Research Flight.

The MRF uses Royal Air Force aircraft with RAF aircrew. The RAE provides the facilities for operating the aircraft and also for designing and carrying out the modifications to the aircraft and their equipment needed to fit them for their meteorological role. This is an extremely important part of the RAE service since the instrumentation of the aircraft is not static: items are replaced as development continues to produce new or improved sensors and recording facilities.

The 25 civilian staff of the MRF are employed by the Meteorological Office. These include research scientists as well as personnel concerned with the 'facilities' side of the unit which includes workshop staff, electronic engineers and computer programmers. There is also a small team engaged on maintenance and development of the meteorological instrumentation installed on the aircraft. Most of the staff are expected to fly, the total flying hours being about 600 per year.

Aircraft and instrumentation

(a) *General*

At present the MRF possesses two aircraft, a Canberra PR3 and a Hercules W Mk 2 (Lockheed C-130). Both aircraft have been extensively modified, both internally and externally, to cater for their new meteorological research roles, and many sensors of meteorological parameters have been installed. Fundamental to the research capability of the aircraft is a comprehensive data-recording system. The present recording medium is 1-inch magnetic tape across which are written 16-bit 'words' (11 bits of data) sequentially at a rate of 640 words per second. Up to 47 channels of a mixture of digital and analogue data can be recorded with sampling rates for each parameter varying from 2 to 80 per second, depending on spatial resolutions required and the performance of the instrument. Both aircraft are fitted with this type of recorder. On the ground, before data reduction and analysis are possible, it is necessary to transcribe the data into a form suitable for input to a large computer. To achieve this, there is a small computer (a PDP8/I), housed in the MRF building, which carries out some quality control on the data and then writes them in suitable blocks on ½-inch computer-compatible magnetic tape. Further processing and scientific analysis is achieved on the ICL computers at the RAE.

Both aircraft possess similar instrumentation for the measurement of the basic meteorological and avionic parameters such as air temperature, humidity,

wind, height, airspeed and position. Thus they both have nose booms integrated with the aircraft framework and projecting sufficiently far ahead of the main fuselage (5 m for the Canberra, 7 m for the Hercules) so that the air at the extremity is not affected by the presence of the aircraft. The probes at the tips of the booms measure static and total pressure (for the determination of height and airspeed) and also carry pairs of sensitive wind vanes (see, for example, Plate VI showing the Hercules vanes) to measure angle of attack and angle of side-slip. These, together with 'stable platforms' (inertial navigation systems) mounted at the base of the boom (for the Hercules) or in the bomb-bay (for the Canberra), allow the determination of the three components of the wind with absolute accuracies better than 1 m s^{-1} and 0·1 m s^{-1} for the horizontal and vertical components respectively. Both booms have resonant frequencies of about 15 Hz; energy spectra are therefore limited to frequencies below about 10 Hz.

Much of the remaining equipment is peculiar to each of the aircraft, so it is easier to consider them in turn.

(b) *Canberra WE 173*

This aircraft, a PR (Photographic Reconnaissance) 3, has been at MRF since 1964 and was reconditioned in 1970/71 (see Plate VII). It has a ceiling of about 15 km—this is considerably less than a standard PR3, the reduction being due to an increase in weight and drag caused by MRF equipment attachments—and an endurance of about 3½ hours. As well as a pilot and navigator, it normally carries an MRF observer seated alongside the navigator. The observer monitors and occasionally controls the outputs of the meteorological sensors as they are fed to the data-recording system. He also measures, manually, the humidity of the outside air by cooling it to its frost-point/dew-point. This is achieved by using a Dobson–Brewer frost-point hygrometer, an instrument designed more than 25 years ago but still one of the most reliable methods of directly measuring the humidity of very dry air.

Other instrumentation on the Canberra includes:

(i) *A sub-millimetric interferometer.* This instrument, developed by the National Physical Laboratory, receives radiation in the wave-number interval from 8 to 40 cm^{-1}, within which occur emission lines from several of the gases in the stratosphere, in particular water vapour, oxygen, ozone and the oxides of nitrogen. In level flight the principal axis of the optical receiver is inclined upwards at about 10° to the horizontal, the measured radiation then being a weighted mean of the emission from gases above the aircraft flight level; most of it comes from the first few kilometres.

(ii) *Downward-facing radiometer.* This is a modified version of the multi-channel radiometer designed by the Department of Atmospheric Physics of the Clarendon Laboratory, Oxford, and installed in the NIMBUS-E satellite. In the aircraft version the 12 channels are used to detect radiation in discrete wavelength intervals from 3 μm to 50 μm, and in a broad band above 100 μm.

(iii) *Upward-facing radiometer.* This also is an instrument designed by the Clarendon Laboratory, Oxford, and has three channels measuring radiation in the infra-red at about 12 μm, 50 μm and 100 μm.

(iv) *Particulate samples.* Two filters, carried in special pods below the aircraft fuselage, can be exposed individually at the height of interest. They have been

useful in the past as part of the Atomic Energy Research Establishment's program to monitor atmospheric radioactivity.

(v) *Gas samples.* Samples of the outside air may be taken by attaching evacuated stainless-steel containers to the hygrometer intake probe. The connection is made via a manually operated piston which allows pressures of up to 1·3 atmospheres to be obtained in the containers.

(c) *Hercules XV 208*

This aircraft was extensively modified for its meteorological research role and was delivered to the MRF in January 1974. It has a ceiling of about 11 km and a maximum endurance of more than 12 hours at its optimum height of about 8 km. It is also able to operate for more than 8 hours at low levels—below 150 m and occasionally for short periods at 30 m over the sea. Normally the aircraft carries five aircrew (two pilots, navigator, engineer and load-master) and, depending on the type of project, four or five scientists.

The major modification to the aircraft—and indeed the most obvious to the eye—was the building of a 7-m nose probe in order to expose scientific instruments in undisturbed air. This necessitated the removal and repositioning of the aircraft precipitation radar which was formerly located in the nose of the aircraft. A special pod was constructed to house the radar and was erected on top of the fuselage just aft of the aircrew cabin. Although primarily intended as an operational storm-warning radar, it finds use in research projects involving precipitation. Its output can be photographed automatically and the range of elevation scan programmed and controlled on suitable occasions by the MRF scientists.

Other major modifications were:

(i) *A recorder/control van* (Plate VIII, upper). The interior of the fuselage of a Hercules aircraft is very noisy and is not conducive to lengthy periods of scientific endeavour. Rather than attempt to sound-proof the entire fuselage it was decided to construct an acoustically and electrically quiet cabin or caravan in which the scientists and their control and monitoring equipment could be housed. The van measures about 4 m × 2 m × 2 m and can be removed from the aircraft at times when the aircraft has to undergo extensive servicing away from Farnborough (every 9 months or so). At these times the van is housed in a specially constructed bay, attached to the MRF building, where there are facilities for supplying the full range of aircraft power supplies, together with comprehensive test equipment for the instrumentation. Tests and calibration of the equipment in the van can thus be conducted independently of the aircraft.

The van is divided into two sections by equipment racking which, together with the racking at the forward end of the van, houses most of the control and recording equipment associated with the meteorological equipment—including the data-recording system described earlier. Up to four scientists can be seated in the van, performing quite different functions. In the two front portions are situated the control panel for the data-recording system (Plate VIII, lower) including the facility to inspect each of the 47 inputs, the slave display of the output of the E290 radar—this can be photographed at 1-second intervals—and a variety of controls for minor functions such as opening doors for the downward-facing camera and radiometer. It is important for the efficient conduct of the flight that a certain discipline is maintained. Consequently a

'flight leader' is nominated before flight. He will be fully aware of the scientific requirements of the flight and the possible limitations imposed thereon by extraneous constraints, e.g. air traffic control regulations. He sits in the port forward seat of the recorder van and is usually the only point of contact between the scientists and the aircrew; any modifications to the flight plan are channelled to the aircraft captain by the flight leader. His other main task is to monitor the inputs to the data-recording system.

The two scientists seated in the rear of the van monitor and control a variety of instrument displays and calibration facilities. For example, the 'sea surface temperature' (obtained as an upwelling radiance in the 8–14 μm wavelength 'window') can be displayed digitally and also as a continuous record by a pen recorder. Calibration of the radiometer can be effected remotely by sliding into its field of view a black body whose emissivity is known. Its temperature can be controlled from the van and adjusted so that a calibration can be obtained close to the sea radiation temperature being measured.

It is important for the flexibility of the flight plan that a certain amount of real-time data is available. Much of the flying is concerned with the presence of sharp gradients in atmospheric parameters, e.g. temperature inversions or steep hydrolapses, and an immediate indication of the location and magnitude of the gradient is essential for the correct positioning of the flight. This is largely the responsibility of the scientist in the port rear seat of the van.

The starboard rear position is normally reserved for scientists who are developing or proving new instrumentation. Although the instrument itself will probably be sampling from the fuselage its performance is monitored inside the van. When development and testing are complete, the instrument becomes a part of the operational equipment of the aircraft and most of the associated electronics are installed outside the van.

In order to allow all four scientists in the van a view of conditions outside the aircraft (there are no windows), two TV monitors are installed which show the view ahead $\pm 60°$ of the aircraft. If nothing else, these displays prevent the development of acute claustrophobia! The van is fitted with its own air-conditioning unit to allow complete independence from that of the aircraft.

(ii) *A dropsonde ejector.* Some of the research projects at present being planned require frequent vertical soundings (temperature, humidity, wind) of the atmosphere. To do this directly by the aircraft would be extremely inefficient and, indeed, impossible when required at shorter intervals than 30 min or so. Consequently the aircraft is fitted with a device which ejects 'dropsondes'—instrumented packages with meteorological sensors and telemetry—from the rear door. Signals from the sondes, including LORAN-C signals for determination of wind, are received by equipment within the aircraft and recorded on magnetic tape.

(iii) *An air-sampling boom.* It is essential to have a facility which allows instruments to be exposed in flight and then withdrawn into the aircraft. (For example, filters to catch aerosols need replacing for a change in flight level.) For an aircraft with a pressurized fuselage it is necessary that the exposure platform preserves the pressure seals but still allows flexibility in the type of instrument exposed. The system installed will cater for sampling heads of up to 150 mm diameter, which, when the boom is fully extended, are positioned about 1 m away from the fuselage. The exposure position is, of course, well ahead of the aircraft propellors.

As well as these major installations, the aircraft is now equipped with a variety of sensing instrumentation including:

(1) Sensitive thermometers for measuring air temperature.
(2) A radiometer sensitive to radiation in the 8–14 μm 'window' to measure sea surface temperature and cloud temperature.
(3) Three instruments for measuring humidity, namely a Dobson–Brewer frost-point hygrometer, an automatic frost-point hygrometer and a microwave refractometer.
(4) A Knollenberg Axially Scattering Spectrometer Probe (ASSP): this is an instrument which gives cloud-droplet-size spectra by observing the light scattered from a continuous laser beam.
(5) A cloud liquid-water-content meter.
(6) Pairs of pyranometers and pyrgeometers, one of each measuring upward and downward solar and infra-red radiation.
(7) Cameras facing forwards and downwards, with automatic and manual controls (located in the van).
(8) An air-sampling pipe by which outside air, from well ahead of the propellor line, can be drawn into the aircraft and vented out again.

The research program

The facilities of the MRF are developed and used for research work not only by the scientists in the Flight itself, but also by various research branches of the Meteorological Office. Furthermore, the facilities of the Flight are available to outside users—there is a long-standing association between the MRF and several universities—for appropriate meteorological projects.

It will be evident that the performances of the two MRF aircraft are quite different; by and large the Hercules is used in the troposphere and the Canberra in the upper troposphere and lower stratosphere. Occasionally the two aircraft are used simultaneously on the same project, but in describing the MRF research program it is probably better to deal with each aircraft independently.

(a) *The GARP Atlantic Tropical Experiment (GATE)*

GATE was an international experiment organized by the World Meteorological Organization to study energy exchange processes between sea and air over the tropical ocean on scales from tens of metres up to thousands of kilometres. The program consisted of three periods of intense observational activity in late 1974 involving a large number of surface and upper-air stations on land and also many ships and aircraft, in a band across the Atlantic from the equator to about 30°N. Up to 10 aircraft, based at Dakar, Senegal, were involved in flights which ranged from near the sea surface up to about 15 km, usually in or near a specific area where specially instrumented ships were concentrated, the objective being to intercept well defined meteorological features, e.g. cloud clusters, and to examine them thoroughly.

The MRF Hercules was one of the three aircraft involved which had the capability (provided by the stable platform and the sensitive wind vanes) to measure small-scale eddies in the air. (This combination of instruments has become known as a 'gust probe'.) Furthermore, the refractometer and fast-response thermometers enabled spectral distributions of the fluxes of heat and water vapour to be obtained, quantities highly important in any assessment of

sea–air interaction. This meant that for most of the experiment the Hercules was used at relatively low levels, i.e. below 2 km.

Altogether, for the three intensive observational periods (each of 3 weeks) in GATE, the Hercules participated in 40 operational sorties amounting to more than 350 flying hours. Data were recorded in transit to, as well as in, the operational area, the quantity of data collected reaching a total of close to a thousand million (10^9) words.

Processing of the data into the format required by the GATE experimenters necessitated several stages in computation. As well as the initial pass through the MRF PDP8/I computer to produce the computer-compatible tapes, two further passes were required through the ICL computers at the RAE. Finally the IBM computer at the Meteorological Office at Bracknell was used to transform the data into IBM format. Since the aircraft and its equipment had only been delivered to us a few months before the GATE experiment, the early part of the data processing was very much a matter of trial and error. Idiosyncrasies in the behaviour of sensors/aircraft configuration only came to light by careful scrutiny of the data, and much hand as well as electronic computation was required. The total amount of computing time was almost 2500 hours, that is nearly seven times flight time. The bulk of this was borne by the RAE staff who initiated extra week-end and night working in order to process the data on a reasonable time scale. Even so, and with about eight MRF staff involved full time, the data reduction was not completed before March 1977, almost $2\frac{1}{2}$ years after the end of the experiment.

But the MRF involvement with this great experiment is not yet over. The scientific analysis of the data is being achieved, in the main, by five research groups who were included in the planning of the experiment. One of these, the Boundary-Layer Sub-Group, located at the National Center for Atmospheric Research (NCAR), Boulder, Colorado, has been analysing data from the three gust-probe aircraft. During the experiment itself, considerable emphasis was placed upon calibration of aircraft instrumentation, both absolutely (relative to instruments mounted on a tall tower) and also relative to the other participating aircraft. The NCAR groups have demonstrated that the measurements made by the aircraft with gust probes are extremely self-consistent and hence scientific analysis, using all three aircraft simultaneously, can proceed with confidence. A scientist from MRF is now participating actively in this work at Boulder.

(b) *Boundary-layer studies*

Following the success of the aircraft in GATE, it was decided to expand the MRF research program to include investigation of the lowest kilometre or so of the atmosphere in a variety of meteorological situations. Since low flying is difficult over land, the first series of flights has been conducted over the sea. Level runs, along and across the mean wind, are made from as low as 100 ft above the sea up to the top of the boundary layer, frequently determined by a temperature inversion. Fluxes of heat, momentum and water vapour can be derived from the measurements as well as mean vertical profiles of temperature and humidity. More recently, in association with measurements made from a tethered balloon by the Meteorological Research Unit at Cardington, Beds., flights have taken place within the boundary layer over land. Because of flight restrictions, it is now necessary to fly a fixed L-shaped pattern with the lowest level 250 ft above the ground. Nevertheless, the combination of balloon and

aircraft data will provide valuable data on the nature and variability of the lowest atmospheric layer.

In 1978 the boundary-layer studies are to be continued in an international experiment named JASIN (Joint Air–Sea Interaction). Organized primarily by the National Institute of Oceanography (now the Institute of Oceanographic Sciences), this international venture will attempt to measure ocean–atmosphere interaction in the vicinity of Rockall where the interactions may be expected to be very different from the tropical ones studied in GATE. The MRF Hercules will be involved, together with two other aircraft, measuring fluxes of heat, water vapour and momentum in a small area well populated with research ships, some of which will fly instrumented tethered balloons.

(c) *The structure of fronts (Project Scillonia)*

One of the research projects of the Cloud Physics Branch of the Meteorological Office involves the investigation of the factors determining the distribution and intensity of frontal rainfall. It is fundamental to the investigation that the meteorological variables—temperature, wind and humidity—be defined accurately and with small spatial resolution within a volume of air of dimensions roughly 100 km × 100 km × 10 km so that any mesoscale structure can be detected and followed. Preliminary experiments conducted near the Isles of Scilly 5 to 8 years ago, when wind fields were observed with high accuracy by tracking falling radar reflectors, were sufficiently encouraging for the project to be extended. This has meant the development, by the Cloud Physics Branch, of an instrumented package—a dropsonde—which can be ejected from the aircraft. Its descent is retarded by a parachute which is designed to follow the wind. Part of the instrumentation on the sonde receives LORAN-C navigation signals so its position can be continuously established. Variations of position give the mean wind over the time interval considered. The basic accuracy of the measurement is dependent on the inherent accuracy of the navigational beacon system which is particularly good over the North Atlantic.

The package falls at 7 to 10 m s^{-1}, depending on its height, so that when dropped from 10 km it takes about 15–20 minutes to reach the ground. The signals from five dropsondes can be recorded simultaneously in the aircraft. For an aircraft with a ground speed of, say, 100 m s^{-1} the system gives a capability of a full sounding about every 20 km. Preliminary trials are still progressing and it is hoped to carry out the first full-scale investigation in 1978 when up to 100 sondes will be dropped.

(d) *Chemical sampling of the atmosphere*

Over the past 10 years or so, there has been increasing concern that physical and chemical balances of the atmosphere are being adversely influenced by human activities on the ground and in the air. Thus, for example, it has been suggested that SO_2 injected into the atmosphere by combustion processes in the UK may be responsible for enhanced acidity of lakes in Scandinavia.

For the past 5 years, using first a Varsity aircraft and then the Hercules, MRF has been sampling air at various heights downwind from SO_2 sources in the UK in order to determine how much, if any, does reach Scandinavia. Air is drawn through a pair of filter papers—the first one catching the SO_4 particulates and the second absorbing the SO_2 gas—via a specially designed sampling head which is exposed to the airstream on the air-sampling boom.

This position is well ahead of the aircraft propellors and sufficiently far away from the aircraft skin to give confidence that the samples so obtained are free from contamination due to the aircraft itself. The results from the flights have been analysed and published by the Boundary Layer Branch. This work may soon be extended in a co-operative project with the Central Electricity Research Laboratories at Leatherhead in which the plumes from individual power-stations will be located and sampled to study in detail the subsequent fate of material emitted from these stations.

The possible effect of an increase in the total amount of man-made 'freons' in the atmosphere has been widely discussed. Both of the MRF aircraft have been equipped with a simple sampling device by which air outside the aircraft can be drawn into clean stainless-steel bottles which can be sealed and returned to ground for analysis. Furthermore, it is hoped soon to install a gas chromatograph on the Hercules so that semi-continuous sampling will be possible.

The Canberra aircraft is also used extensively to investigate the chemical composition of the lower stratosphere. The construction of the Dobson–Brewer manual hygrometer more than 25 years ago gave MRF the capability of observing very low frost-points and so measuring water-vapour mixing ratios typical of the lower stratosphere, namely between 1 and 10 parts per million (ppm). The results of the earlier investigations conducted from Mosquito and then Canberra aircraft from about 1945 to 1955 are regarded internationally as the definitive measurements illustrating the dryness of the lower stratosphere. More recently, an analysis has been completed of regular measurements up to about 14 km ($\approx$ 47 000 ft) over southern England made from 1971 to 1976. This suggests that since the 1950s there has been an increase from about 2 to 3 ppm in the average value of stratospheric mixing ratio, but that there is evidence of a decrease between 1972 and 1976. On the basis of these results, the flight strategy has been changed from regular weekly soundings to four periods during the year (at 3-monthly intervals from the expected maximum) when 10 flights are conducted over a few weeks. The flights have also been extended to cover a wide range of latitude from 45°N to 68°N.

The sub-millimetric interferometer installed on the Canberra measures emitted radiation in the region from 8 to 40 cm^{-1} which includes radiation from water vapour, ozone, oxygen and the oxides of nitrogen. Although only a few successful flights have so far been achieved, it is intended to operate this instrument in the program of regular stratospheric soundings described above.

(e) *Orographic influences*

The disturbance to an airstream caused by mountains is frequently important meteorologically and is occasionally hazardous to aircraft. Part of the research program of the MRF is concerned directly with the investigation of such phenomena at all levels from near the ground to the lower stratosphere, involving sometimes both the Hercules and the Canberra. Since 1973 flights have been conducted to measure the vertical flux of horizontal momentum caused by airflow over mountains. In particular, a series of flights involving several aircraft including the MRF Canberra was carried out over the Rocky Mountains in collaboration with aircraft from the National Center for Atmospheric Research (NCAR) at Boulder, Colorado. Altogether 20 flights were made, though on only a few occasions were the disturbances caused by the mountains very large. The data are still being analysed.

More recently, flights have been made over the mountains of Scotland and Wales and also, on detachment, over Norway. The purpose of these flights was primarily to obtain quantitative estimates of the vertical flux profiles in a variety of synoptic situations. These can then be used as a check of the predictions of theoretical models, and can, if necessary, be incorporated in global circulation models.

(f) *Clear-air turbulence*

It is widely known that aircraft occasionally experience significant turbulence well away from any cloud. Although much of this can be associated with orographic effects, such as those described above, there are still a large number of incidents which do not fall into this category. Much of the work of MRF in the past has been concerned with measurements in regions where clear-air turbulence was expected to occur. In 1972 a series of flights was conducted in collaboration with staff of the Meteorological Office Research Unit at the Royal Radar Establishment, Malvern, who employed a high-powered Doppler radar to detect the turbulent layers, usually near the tropopause, caused by breaking Kelvin–Helmholtz waves. Direct air–ground communication enabled the Canberra aircraft to be flown through the region where waves were detected so that accurate measurements could be made, not only of the turbulence itself but also of the meteorological parameters associated with the environment in which wave development and subsequent breakdown occurred.

(g) *Cloud physics*

The Cloud Physics Branch of the Meteorological Office is by far the biggest user of MRF facilities and, in particular, the Hercules aircraft. Project Scillonia has been mentioned in para. (c) on page 77; other projects include studies of convective cloud, the factors controlling the size spectrum of water and ice particles in cloud, cloud electrification and radiative processes affecting clouds. Much of this work involves development, testing, and subsequent installation on the aircraft of special instruments, and this phase is still not complete.

About 5 years ago, before the arrival of the Hercules aircraft, a series of flights was conducted to investigate electric fields in and around developing cumulus clouds. A field mill, designed by the Cloud Physics Branch and constructed in the MRF workshops, was mounted in the nose of the Varsity aircraft. It measured two components of the electric field—the horizontal component parallel to the aircraft wings and the vertical component. At the same time, a dropsonde was developed by the Department of Physics, University of Manchester Institute of Science and Technology (UMIST), which could be ejected through a tube through the tail-cone of the aircraft. The sonde carried a pair of field mills (to measure all three components) as well as pressure and temperature sensors, the measurements being transmitted to a mobile ground station. The UMIST also installed a pair of air conductivity probes and a cloud-droplet charge-detector on the aircraft. Interesting data on the variability of the electric field in anticyclonic conditions were obtained.

Satellite photographs have confirmed that over the globe there are always vast areas of stratocumulus cloud, particularly over the sea or over land near the sea. The presence of this cloud has considerable effects on the earth beneath, reducing significantly the amplitude of the diurnal temperature variation and possibly preventing the formation of nocturnal fog or frost. The cloud,

sometimes only a few hundred metres thick, is remarkably persistent and poses something of a challenge to the cloud physicist. Several series of flights have been carried out with Hastings and Varsity aircraft since the mid 1950s to examine some (but not all!) of the properties of this type of cloud and its environment. It appears that the various physical and dynamical processes which maintain stratocumulus sheets are finely balanced and that only a slight change in one or more of them could cause the cloud to break and then dissipate rapidly. With the new instrumentation on the Hercules—in particular the gust probe, radiometers and droplet spectrometer—it is planned to attack this problem once more.

(h) *Radiation*

The Canberra is fitted with a pair of multi-channel radiometers looking vertically upwards and downwards. These have been used to investigate the radiative properties of cirrus cloud in a number of discrete wavelength intervals from 3 μm to 100 μm and also to measure the transparency of the atmospheric 'windows' near 3·5 μm and 11 μm. This latter project is particularly important as recent satellite measurements of sea surface temperature have indicated a significant difference between the true and derived equivalent black-body temperatures. Much of this, it is thought, is due to the non-transparency of the 'windows' with the water-vapour dimer,* $(H_2O)_2$, playing an important part. In 1975 the aircraft carried out a series of flights over the Atlantic Ocean near Dakar, Senegal, where the dimer concentration would be expected to be large in the hot, humid surface layers. The data are being analysed by the Department of Atmospheric Physics, Clarendon Laboratory, Oxford.

The Hercules has just been equipped with pairs of Eppley pyranometers and pyrgeometers. These will help resolve difficulties in past investigations of the boundary layer where differences between results from alternative methods used to calculate energy transfers are thought to be due to inadequate representation of radiative processes.

The Barnes radiometer, looking downwards from the Hercules aircraft, measures upwelling radiation in the wavelength region from 8 μm to 14 μm. It has been used extensively over the sea during boundary-layer flights to measure the surface temperature and also as a detector of 'frontal boundaries' in the sea itself. In the late 1960s and early 1970s, the Varsity aircraft of MRF, fitted with this radiometer, carried out a series of oceanographical studies of temperature discontinuities in the Mediterranean Sea to the east of Malta. The aircraft was used primarily to search for a suitable area where there was a significant (greater than 1 °C) and rapid change of sea surface temperature. Further investigation would then be carried out by divers operating from ships directed to the area. More recently the Varsity, and then the Hercules, was used to measure sea surface temperatures in the Irish Sea in conjunction with the Department of Oceanography of the University College of North Wales, Bangor, which also employed ships in an oceanographic survey of the area.

Future work

In the last few years the emphasis of the MRF effort has been on the development and installation of comprehensive instrumentation on both aircraft of the

*Dimer: molecular species formed by union of two like molecules.

Flight. These activities have always been seen as the necessary prelude to a program of detailed studies of the intricate features of the real atmosphere of the type that can only be achieved by using a highly instrumented flying laboratory. We are now on the threshold of this most exciting prospect and the next few years will see the MRF making major contributions to the Office's research program, especially in the fields of cloud physics, cloud dynamics, boundary-layer processes and atmospheric chemistry.

Of course the further development of instrumentation will continue, albeit in a lower key, especially for cloud physics and cloud electrification work on the Hercules, which is expected to continue in its role of a major research tool for the next 10 to 15 years. The importance of the Canberra's role has been enhanced in recent years by the increased interest in, and speculation about, the importance of pollution in the stratosphere. However, this aircraft, because of its age, will need to be extensively refurbished or replaced in 1982/83. Until that time its role in monitoring the stratospheric composition and in studies of the atmospheric radiative properties will be continued. The Canberra's limited ceiling of 13 to 14 km is a severe restriction for its stratospheric role (it means, for instance, that it cannot reach the stratosphere in the tropics). We hope that a suitable aircraft, capable of reaching 20 km, will become available within a few years.

Physical Research

Cloud physics

The main emphasis of our work in the last year has been on the study of clouds in the real atmosphere, rather than on laboratory experiments, and on the development of numerical models which represent all the main processes responsible for clouds and precipitation.

Much effort has gone into equipping the Hercules aircraft of the Meteorological Research Flight (described in the Special Topic (page 71)) for the comprehensive study of clouds. The main tool for studying the large-scale structure and dynamics of cloud systems is the 'dropsonde' system (page 74) whereby the aircraft can drop devices to measure wind, temperature, pressure and humidity at many points over a large area in a fairly short time. The equipment for tracking the sondes and receiving data from them has been tested in flight and is working well but there have been some difficulties in achieving—and demonstrating the achievement—of the necessary high degree of reliability and safety in the system which ejects the sondes from the aircraft. These have delayed the introduction of the system into operational use, but it is hoped that they have now been overcome and that large-scale measurements will start in 1978.

Development of instruments for microphysical measurements in cloud has also continued. Installation on the aircraft of a device to record all the cloud droplets and ice crystals within a volume of about 0·5 litre in the form of a hologram is now under way and the arrangements for automatically counting and sizing the images on the hologram have been further developed and tested. New instruments and techniques to determine the concentration of aerosol particles, particularly the nuclei on which cloud droplets form, are being studied and developed for aircraft use.

Cumulus clouds have been studied both in flights of the Hercules aircraft,

on which the growth rate and pattern of the clouds have been observed in measured environmental conditions, and by the development of a three-dimensional numerical model. The model already gives a reasonable representation of the observations, but detailed intercomparisons point the way to improvements in the model and help to identify the crucial observations. On a smaller scale, observations have been on the spatial distribution of air motions and of drop sizes and concentrations in cloud; these are being used to study the mixing of cloud and cloud-free air.

Layer cloud (stratocumulus) has been studied by instruments carried on a tethered balloon at Cardington (following earlier work which has contributed much to our knowledge of fog). Attention has been concentrated on the energy exchanges at the top surface of the cloud, and this has led to the development of a model of the physical processes at work which emphasizes the importance of the mixing of clear and cloudy air and should be capable of extension to include all the factors controlling the cloud.

Atmospheric chemistry

Efforts to improve the monitoring of the chemical composition of the atmosphere continue. Besides the routine measurement of the chemical composition of rain-water collected at Lerwick, Eskdalemuir and Bracknell and the measurement programs for atmospheric ozone and nitrous oxide, a gas chromatograph capable of measuring the concentration of several other important trace constituents of the atmosphere has been developed. The chromatograph is being used initially to analyse air samples brought back from flights of the MRF aircraft. A more sophisticated version of this chromatograph is now being constructed which will be installed on the aircraft and so allow in-flight measurements to be made.

The atmospheric boundary layer

The boundary layer—roughly speaking the lowest kilometre of the atmosphere—is important, not only because it provides the immediate environment for many human activities, but also because it achieves the transfer of heat, momentum and moisture between the earth's surface and the atmosphere above.

Several major field experiments measuring the structure of the atmospheric boundary layer over land have taken place during the last decade. Prominent amongst these was the Minnesota experiment carried out jointly between the Meteorological Office's Cardington team and the American Air Force Cambridge Research Laboratories' team. The former team used their tethered-balloon system to measure properties of the turbulence at several levels simultaneously throughout the boundary layer, using instruments supported on the balloon cable. Most of these data have now been worked up. In conjunction with the results from the other major experiments, much of which has been analysed and 'digested' by other scientists, a fairly complete and consistent picture of the internal structure of the boundary layer has begun to emerge, at least over level uniform terrain and in fairly simple meteorological situations. One important challenge has been to throw these data into so-called similarity form (i.e. to normalize them in terms of external parameters) so that confident predictions can be made about the structure in situations not directly covered by the field data.

This has now been done, at least for those important parameters that have a direct bearing on the dispersion of plumes from chimneys and other sources. In consequence, schemes are now emerging, more firmly based on observations than hitherto, that predict dispersion and ground-level concentrations downwind from either elevated or ground-level sources in terms of the relevant external parameters (e.g. cloud type and amount, surface roughness and type, time of day etc.).

During 1977 the Organization for Economic Co-operation and Development (OECD) project to study the long-range transport of sulphur pollutants over Western Europe came to an end. Whilst argument still rages over the ecological effects of acid rain, some claiming that no totally consistent evidence has yet been presented to support the claim that damage is occurring due to this cause, the project has shown that long-range transport does occur to a significant degree, that modelling, even very simple modelling, can give a broadly correct idea of how much one country contributes to another and that often the hardest task is to estimate how much *local* sources contribute to the net deposition of sulphur to the ground.

Another detailed point studied during the year has been the conditions leading to unusually high deposition of sulphate in precipitation. These 'episodes', occurring a few times a year, contribute a substantial fraction of the total annual sulphate deposition and it has been found that they are often associated with complex meteorological situations not adequately represented by the current rather simple models.

Preparation continues apace for the major international experiment known as JASIN (Joint Air–Sea Interaction Experiment) to be undertaken in the summer of 1978 in an area of the North Atlantic near Rockall. In JASIN, it is planned to study the details of the upper layers of the ocean as well as the lower layers of the atmosphere and the interactions of both with the larger scale motions of air and sea. A major contribution to JASIN is being made by the unit at Porton, which will be responsible for a meteorological program to study the vertical fluxes of heat, momentum and water vapour using measurements from buoys, ships and tethered balloons as well as special radiosonde ascents. The measurements will be extended upwards and over a wider area by aircraft, including one from the Meteorological Research Flight.

Further experiments with acoustic sounders have been carried out in collaboration with the Department of Electronic and Electrical Engineering of University College, London. The vertical component of wind has been measured by measuring the Doppler shift in frequency of a sound pulse reflected back from inhomogeneities in the lower atmosphere. Comparison with direct observations from a tethered balloon has shown that satisfactory measurements can be made up to heights of about 500 m. The method is being developed to measure horizontal components as well, using receivers some distance away from the sound transmitter.

The study of low hills and mountains which affect the atmospheric wind field has continued. This study has bearings on how orography should be included in numerical forecasting models and also on how pollution behaves in different atmospheric conditions as it is blown over complex terrain. A three-dimensional numerical model of flow over a hill has now been developed and the results are very encouraging. Two features may be mentioned: firstly, an isolated hill or ridge, the height of which is less than that of the boundary layer,

gives rise to virtually no net increase in the surface drag between air and ground, even when the slopes are sufficiently steep to give rise to steady separate flows in the lee of the hill. Secondly, hills with heights comparable to the boundary-layer depth can trigger stationary longitudinal rolls that persist for considerable distances downstream and have vertical and horizontal dimensions of the same order as the boundary-layer depth: in this case the total surface drag is significantly increased. Rolls with these characteristics have been observed by the high-power radar at Defford. Measurements of the wind over and around the isolated hill at Brent Knoll in Somerset have been made in an attempt to provide atmospheric data to test the theoretical and numerical work on flow over hills.

Radar meteorology

The ability to observe clouds and precipitation has been greatly improved by recent advances in radar and satellite imagery. These hold considerable promise for improving local forecasts for periods up to 12 hours ahead. This is an area of great practical importance which so far has not benefited in a major way from improvements in numerical–dynamical modelling. Accordingly a Short-period Weather Forecasting Pilot Project is being set up to develop techniques to improve, in particular, the short-period forecasts of precipitation and strong surface winds, and to optimize the impact of such techniques on the forecasting capability of the Meteorological Office. The pilot project, which is centred at the Meteorological Office Radar Research Laboratory at Malvern, is a 5–8 year program. It is intended to be from the outset a balanced program of fundamental and applied research. During the year, work began on the first major objective, which is to interlink a number of weather radars and to develop facilities for handling the data from the radars, and also from satellites, in such a way as to provide displays showing the rain and cloud existing over a fairly large area of the country. In the coming years it is planned to operate these facilities so as to:

(a) optimize (in the light of practical experience, and with help from staff at the Royal Signals and Radar Establishment (RSRE) at Malvern) the methods of displaying these new forms of data;
(b) exploit the data to improve our basic understanding of the structure, mechanism, evolution and predictability of precipitation and associated wind systems;
(c) develop simple analytical procedures to optimize the use of these data for the provision of improved forecasts of precipitation and wind (initially over a period of a few hours but with a view to extending the period of improved forecasts to 6–12 hours);
(d) assess from practical experience the utility of the new observations and forecasts to users; and
(e) assess the desirability and the most cost-effective way of extending the mesoscale observational network and forecasting techniques.

Data obtained in a previous field project in South Wales are being analysed to study the structure and mechanisms of heavy orographic rain generated when strong moist airflows approach the hills of South Wales from the sea. Conventional and Doppler radars were used in this project, together with sequential rawindsondes. The data are being analysed in an attempt to describe

and account for the large increment in rainfall intensity that can occur in the lowest 2 km of the atmosphere in the vicinity of the hills. The tendency for a large amount of growth to occur at such low levels is also being considered from the point of view of the difficulties it poses in the measurement of surface rainfall by means of radar, especially when the radar is at long ranges and cannot easily observe the precipitation close to the ground.

Another study using data from the Shannon radar of the Irish Meteorological Service in addition to those in Wales, has been concerned with the persistence and predictability of the mesoscale precipitation areas some tens of kilometres across that occur within some warm sectors. Although the intensity of the rain in these areas was modulated in a major way by orographic effects, it was found in a case study that these small areas of rain were in fact very persistent and could be tracked all the way from the west coast of Ireland to south-east England.

Another part of the research program at Malvern involves the use of a high-power S-band Doppler radar at the nearby RSRE site at Defford. Because of its ability to detect echoes from the optically clear air (due to back-scatter from small-scale inhomogeneities in temperature and humidity) this radar is used for studies of clear-air turbulence and the structure of the boundary layer. The angular resolution of this radar is very good as a result of the large size of its aerial (25 m diameter). It is also equipped with a pulse compression sub-system capable of providing a range resolution as good as 30 m. This permits the dynamical structure of the atmosphere to be probed in considerable detail. One such study has shown how shearing instabilities in the upper troposphere concentrated a layer of already strong shear by a factor of up to 8. Over a depth of 50 m the vertical wind shear was observed occasionally to be as great as 0·2 s^{-1}. An important feature of this radar technique is that it provides an all-weather capability for measuring wind and wind shear.

High atmosphere

The project to obtain global daily temperature analyses for the stratosphere on a routine basis has continued to dominate our activities. Central to this project is the construction of infra-red radiometers to be flown on the forth-coming TIROS-N series of US polar-orbiting meteorological satellites. The radiometer, known as the Stratospheric Sounding Unit (SSU), will provide a means of determining the broad temperature structure from 25 to 45 km and forms part of a group of temperature-sounding instruments on the satellite. The instrument exploits the pressure-modulation technique of selective chopping developed at Oxford University. Four flight instruments were completed and tested during the year. Three of these were delivered to the spacecraft manufacturers in the USA. The first instrument was mounted on the TIROS-N spacecraft in June and has since been tested for compatibility with the spacecraft and other instruments. The launch of the first spacecraft is now expected to occur about mid-1978.

Preparations for the reception and processing of the SSU data have been intensified. An agreement was concluded with the National Oceanic and Atmospheric Administration (NOAA) to provide, by private line from Suitland, Maryland to Bracknell, data from the SSU and some of the related instruments on the spacecraft. Good progress has been made with the software which will be needed to handle the incoming data, to monitor the in-orbit performance of the SSU and to generate meteorological products. Tests with simulated data

have begun. Initially emphasis will be placed on analyses of radiance and thickness for the northern hemisphere up to about 0·5 mb. Contact has been established with several potential customers for these analyses in universities and government establishments both in the UK and abroad.

Meanwhile, production of daily northern hemisphere charts at 50, 20 and 10 mb, using radiosonde and rocketsonde observations has continued. It is these analyses which, in the coming year, will provide the basis for controlling the quality of the analyses generated from the SSU data. The study of the major mid-winter warming of 1974/75 at levels up to 1 mb, using radiance data from the Oxford University Selective Chopper Radiometer, was completed. It highlighted some of the problems which can be encountered in handling satellite data in conjunction with conventional observations. The daily series of objective stratospheric analyses together with operational analyses for the lower levels have been used to investigate the dynamics of a very unusual event during the 1976/77 winter. In early January 1977 a warming extended throughout the atmosphere, including the troposphere, with a very intense anticyclone at high latitudes. It appears that eddy momentum fluxes played a fundamental role in the evolution of this warming.

Studies of the interpretation of satellite-sounding data for the troposphere have continued. Further work was done using data from the Vertical Temperature Profile Radiometer (VTPR) on the current NOAA series of polar-orbiting satellites. Topics investigated have included the generation of humidity data and its impact on rainfall forecasts made by the 10-level model, an eigenvector technique for removing the effects of clouds on radiances and a continuation of the use of the VTPR as a means of assessing bias errors between different types of radiosonde. An extension of the latter was the reception at Lasham and processing of VTPR radiances during the special series of Mk 3 radiosonde flights from Beaufort Park in September. However, effort has been increasingly directed towards obtaining experience of the type of sounding data which will be available from TIROS-N, by processing samples of data from similar instruments on NIMBUS-6. A preliminary study has been made of methods which might be used for deriving surface winds over the ocean from data from the scatterometer to be flown on the SEASAT satellite in 1978.

Nearly all the Skua rocket firings from the Hebrides have been timed to coincide with over-passes by the NIMBUS-5 and NIMBUS-6 spacecraft. These satellites carry infra-red radiometers developed by Oxford University for temperature-sounding in the stratosphere and mesosphere. Direct comparisons of the radiances observed by these radiometers and the detailed temperature structure obtained by the rocketsonde are extremely valuable for checking the performance and long-term stability of the satellite instrumentation. Similar comparisons are planned with the Stratospheric Sounding Units, starting next year. Eighteen Skuas have been flown: 15 in the winter campaign between December 1976 and mid-February 1977, and the remaining 3 during September. Again the success rate has been very high; all flights provided complete temperature profiles. Data from the fast printer on the radar has enabled improved estimates of ventilation rate to be obtained and attempts are being made to correct the temperature readings above 70 km.

The first flight of an experiment to measure ozone concentration at night was made in February. This used a Petrel rocket (19 cm diameter) and was part of a program to study the diurnal variation of ozone in the height range 40 to

80 km. The flight was rather disappointing. The system to determine rocket roll and pitch angles relative to the moon did not function and this degraded the output from the ozone sensors. However, the reasons are now understood and useful information on ozone is being recovered. Work is in progress on four payloads to be flown in the course of a single day in autumn 1978, to study diurnal variation. Some advice has been given to the National Aeronautical and Space Administration (NASA) Langley Research Center in connection with the preparation of a satellite experiment (SAGE) to measure aerosol and ozone by the solar occultation technique.

The dye laser installation at Beaufort Park has continued to be used for monitoring of aerosol in the stratosphere. The amount of aerosol present above 15 km remains low. The system has been modified to allow measurements to be made on cirrus cloud. Some of these have been made in collaboration with aircraft of the Meteorological Research Flight which have flown over Beaufort Park to make coincident observations of the radiation fluxes in and around the cloud sheet.

A theoretical study of the uncertainties in determining the concentration of aerosol particles from the laser observations shows that the uncertainties of the microphysical properties, such as size distribution and refraction index, are more important than the errors in the measurements. The importance of obtaining measurements at more than one wavelength or angle was highlighted. By using a more compact laser in conjunction with the high-power laser it is now possible to obtain simultaneous measurements of the scattering at two wavelengths.

The joint project with the National Physical Laboratory (NPL), Teddington, to develop a small broad-band balloon-borne radiometer to measure the concentration of water vapour or ozone in the stratosphere up to about 30 km has made good progress. The first flight was made from Larkhill in September. The radiometer functioned perfectly and gave realistic values of water-vapour mixing ratio in the lower stratosphere. Unfortunately the balloon only reached an altitude of 12·5 km but the radiometer was recovered undamaged and is being prepared for another flight.

Routine Dobson ozone spectrophotometer work has been maintained. The instrument on St Helena was commissioned in January. Together with the ones at Mahé (Seychelles), Lerwick and Bracknell, it has provided routine observations throughout the year. We participated in the international intercomparison of Dobson spectrophotometers, co-sponsored by WMO and NOAA, at NOAA Environmental Research Laboratory in Boulder, Colorado, in August. The Bracknell instrument, which was transported to Boulder for this test, performed very satisfactorily. A spare instrument has been refurbished and is to be made available as part of a WMO program to improve the global network for total ozone. In response to the wishes of Professor G. M. B. Dobson, who died in 1976, instrument No. 2 has been permanently assigned to the Bracknell site. This historic instrument, which is the first production model (made by R. & J. Beck in 1928), enables us to maintain observations and to have a permanent standard whilst our primary instrument is away at network stations. We wish to record our deep gratitude to Mrs Dobson.

Work has begun on the construction of an instrument to measure NO_2 in the atmosphere. It will be recalled that NO_2 is of considerable importance in the photochemical reactions which influence the amount of ozone in the stratosphere. The initial ground-based instrument will detect the absorption of sunlight by NO_2 at wavelengths around 450 nm.

METEOSAT

For the last five years the European Space Agency has been developing a geostationary meteorological satellite—METEOSAT—to provide new data for forecasting and research. The Office has helped to provide support and guidance to the Agency through all the stages of development and planning for operation of the satellite. METEOSAT was launched successfully on 21 November and has already begun to yield data of high quality. One of the recent pictures received is shown in Plate I; near the top centre the British Isles can be seen with the eastern side snow covered. The satellite is geostationary over the equator on the Greenwich meridian and its main function is to provide pictures of cloud and surface features every half-hour, not only in visible light (as in Plate I) but also at two wavelengths in the infra-red, giving extra information on temperatures and water-vapour content. The pictures are received in a central station in Germany and, after processing, they are broadcast via the satellite to receiving stations in many countries. As mentioned elsewhere (page 58), the Office will receive the pictures through the station at Lasham and preparations have been made to use them in routine forecasting and in the development of special methods for short-range forecasting (see section on 'Radar meteorology' (page 84)).

Geophysical fluid dynamics

The high degree of complexity of the atmosphere tends to obscure the fundamental factors which control large-scale atmospheric motions. The main work of the Geophysical Fluid Dynamics Laboratory is intended to explore basic dynamical processes in rotating fluids, of which the atmosphere is but one example. Other natural fluid systems in which rotation plays a dominant role are to be found in the atmospheres of the planets, in the oceans, and in the liquid core of the earth where the earth's magnetism originates.

The studies are carried out using a variety of methods, including the detailed examination of motions in rotating fluids in the laboratory, theoretical mathematical investigations and numerical work using high-speed electronic computers. The laboratory systems provide valuable and stringent tests of mathematical theory and suggest new lines of theoretical research. In the laboratory the experimental conditions can be varied over a wide range and theories thereby tested in a manner which is not possible if they are applied only to the atmosphere. We cannot change the rate of rotation of the earth to see if a theory continues to apply, but we can change the rate of rotation of the fluid container in the laboratory. The combination of laboratory experiments and numerical modelling of the same system provides a unique opportunity to subject numerical models to stringent tests which are not possible in other contexts.

Many features of the large-scale atmospheric circulation can be reproduced in liquid filling a rotating annulus, the inner and outer walls of which are maintained at different temperatures. The transfer of heat by the fluid between these walls simulates the transport of heat from the equatorial regions towards the poles by the wind systems. The laboratory studies show that several different regimes are possible. The flow may be axisymmetric, it may contain a 'jet stream' with wave-like perturbations or it may be highly irregular. Experimental and theoretical studies have established the conditions under which such regimes are to be expected.

During 1977 new apparatus was brought into use which will enable accurate remote measurements of the horizontal velocity fields to be obtained in addition to the usual temperature measurements. These measurements will be used to provide data on the radial structure of the flow without the disturbing effects of large thermocouple arrays. The data from these experiments will be used for detailed comparisons with the predictions of a numerical model of the flow and for the estimation of momentum and energy transports. It is intended to use the apparatus to measure the effects of topographic and thermal forcing on the details of the flow and, in particular, on the non-linear wave interactions. These studies will complement those which have already been undertaken using apparatus with different geometry. Apparatus has been constructed to enable a detailed investigation of the phenomenon of vacillation to be undertaken with a view to the determination of the conditions under which vacillation occurs. Other experimental work which has been undertaken includes studies of (a) the structure and stability of the thermocline in a rotating fluid subject to heating and cooling at the same level, (b) baroclinic instability in a mechanically driven two-layer system, which is readily amenable to analytical and numerical investigation, (c) the flow over and around isolated topography in a rotating system, and (d) the filling of a rotating basin.

Dynamical and Synoptic Research

Research related to numerical short-period forecasting

The Central Forecasting Office currently bases its day-to-day predictions on forecast charts obtained from a computer model designed to represent physical and dynamical processes controlling the behaviour of the atmosphere. The evolution of the wind, temperature, humidity and pressure is predicted at 10 levels from the ground up to a height of about 15 km ($\approx$ 50 000 ft) over two different arrays of points in the northern hemisphere, one with a 100-km grid-point separation covering the North Atlantic and western Europe and the other with a coarser resolution of 300 km covering the whole hemisphere north of 15°N. Predictions are made 36 hours ahead over the fine-mesh area and as far as 6 days ahead in the hemispheric area. A considerable amount of research is currently being undertaken with a view to improving the accuracy and detail of the forecasts.

An extensive series of tests is being carried out using four models, all representing the same physical processes in the atmosphere but having very different mathematical formulations. These are the 10-level model used in routine forecasting, an 11-level grid-point model originally designed for general circulation studies, a 5-level model developed at the Department of Meteorology, University of Reading, which expresses physical variables over the northern hemisphere as expansions of spherical harmonic functions rather than as values on an array of grid points, and a 5-level finite element model which, by contrast, represents physical variables in terms of a series of locally defined functions. The results have been compared and general faults or successes noted. Some of the observed errors have been found to depend on season, some on geographical location and some on the prevalent weather situation. Tests have also been made to see whether improvements can be made to the operational model itself by changing the mathematical procedures employed. The results from these

experiments are being examined in some detail and, as far as possible, the beneficial features of each technique will be incorporated into a future new operational model.

A feature of the network of observations that currently exists (and is likely to exist in the future) is that there are relatively few accurate observations in the tropics and over the oceans, but there is a good supply of less reliable data. Research is being conducted into a number of alternative schemes for analysing data from widely differing sources in an optimum and consistent way. Tests are also being conducted into the importance of including interactions between middle latitudes and the tropics when predicting weather systems of middle latitudes beyond one or two days.

An increasing quantity of atmospheric observations is becoming available at irregular times from aircraft, satellites, automatic weather stations and ships. Research is being undertaken into ways of introducing these into a 'real-time' computer weather simulation so that, at any given time, there exists an up-to-date estimate of the current state of the atmosphere which can be used as a starting point for a forecast. A difficulty is that changes made to the computer simulation as a consequence of introducing an observed value become rapidly dispersed by fast-moving gravity waves. An effective method of preventing this has been found to be to enforce selective dissipation of the fastest moving waves so that their ability to transfer information away from the neighbourhood of the observation is impaired. A scheme using a similar principle has also been developed to ensure that, prior to starting a forecast, the wind and pressure fields are consistent with one another.

In addition to investigating ways of reducing forecast errors by improving the model formulation and the specification of the initial state, a close examination is being made into the nature of the errors themselves in terms of their variations in space and time. If a statistically significant pattern of error evolution can be deduced, it may be possible to apply corrections to the forecasts to compensate for deficiencies whose causes have yet to be identified.

Computer predictions of the large-scale wind, temperature, humidity and pressure fields need to be interpreted by the forecaster in terms of weather elements such as rain, snow, fog, cloudiness, visibility, local wind variability etc. The operational fine-mesh model provides some guidance with respect to rainfall intensity, but a recent survey of the accuracy of forecasts of rain by the computer during the past four years over western Europe has highlighted certain deficiencies. Increasing attention is being paid to improving this aspect of the problem, with particular emphasis being given to frontal and orographically induced rainfall. It is suspected that the interaction of the atmosphere and the boundary layer is an important factor, and work is proceeding into the development of a version of the fine-mesh model with an improved representation of the lower boundary.

One of the difficulties of forecasting rainfall in mountainous regions is the considerable local variability of the precipitation. A scheme which simulates the forced vertical displacements and the concomitant cloud physics processes on a very fine $3\frac{1}{3}$-km mesh has given significantly better rainfall forecasts in Wales for a limited series of case studies.

The dynamic processes giving rise to small-scale local weather variations are being studied using a non-hydrostatic mesoscale model. This research project, which has been under development for a number of years, is now being

applied to several widely differing meteorological situations. Studies are being undertaken into the behaviour of neutral and stable airflow over hilly terrain and into the growth of convective clouds. Integrations have been carried out to predict the formation and movement of sea-breezes around the coast of England and Wales on a summer day when active sea-breezes were in fact observed. Comparisons between the forecast and the observed details of the low-level wind fields and temperature profiles indicate a useful degree of predictability on this scale. The model is at present being used as a research tool with a view to developing improved methods of simulating the net effect of small-scale systems in larger-scale forecasting models, but its use as a forecasting model in its own right may become a possibility if more powerful computing facilities become available.

A detailed study of problems which might arise in using the specialized features available on the next generation of computers efficiently has been made and has indicated that for much of the calculation in the forecast models only a minor reorganization is necessary. However, for certain physical processes having an intermittent or conditional nature, the most appropriate method of doing the computation may depend on the detailed characteristics of the computer being used.

General circulation of the atmosphere

The use of numerical methods to describe and explain the general circulation of the atmosphere began in the Office during the 1960s. The objective is to reproduce the physical and dynamical features which go to make up the average state of the atmosphere, its annual cycle, and the range of possible variation. The numerical model formulated for this purpose has been developed over the years and several versions now exist. There are two basic grid-point versions, differing primarily in resolution; one has 11 levels in the vertical and a horizontal grid-length of 2°, and the other 5 levels and 3°. The former tends to be used to study atmospheric behaviour over shorter periods, of say a month or less, and the latter for extended integrations and ultimately long-period climate simulations. Integrations using these models have to be effected at least over a hemisphere, but more often encompass the whole globe. Such integrations are very demanding in computer time; for instance the present version of the 5-level model when integrated globally would take 70 hours of central processor time on the IBM 360/195 computer to simulate a complete annual cycle while the 11-level model would take considerably longer.

Though extended integrations are clearly not yet possible a good deal can be done with present resources to explore the general circulation. It was shown at an early stage that even when an integration began with the atmosphere at rest and of uniform temperature, provided that values of sea surface temperature and radiation parameters appropriate to a particular season were supplied, the model was able to reproduce quite realistically many atmospheric features remarkably quickly—in only a few weeks, in fact, of simulated time.

During 1977, further experiments of this nature have been conducted. The sensitivity of the results to changes in initial conditions, to variable forcing functions, and to internal changes in model formulation, have been further explored. A number of integrations have been carried out, starting from different sets of initial values but using the same external parameters such as sea surface temperatures and intensity of solar radiation. The results show

significant differences, not only in day-to-day variations of the simulated flow patterns but in averages taken over periods of up to 50 days at least. This suggests that the atmospheric state at any time may exert a significant direct influence on its state for a long time ahead, in addition to the indirect influence exerted through the effects of the initial atmospheric state on external parameters (sea surface temperature, for example) which can, in turn, exert some control over the later atmospheric state.

Computations which try to assess the effect of particular unusually warm or cold areas of the ocean surface on the atmosphere have continued. The method used is to compare integrations with anomalous values of sea temperature with control runs in which average seasonal values are assumed. The results indicate that whereas abnormal sea temperatures in the tropics may have a substantial effect on the hemispheric flow pattern, the atmospheric response to anomalies in higher latitudes is more local. Attempts have been made to relate large-scale abnormalities in the sea surface temperature pattern to observed persistent anomalies in the atmospheric circulation in middle latitudes, such as occurred in the exceptional summer of 1976, but results so far do not suggest that any simple relationship exists.

Experiments have also been carried out to compare global and hemispheric forecasts and hence to assess the impact of developments in one hemisphere on the other. At present they are limited by the fact that no objective numerical procedure exists within the Meteorological Office for analysing the atmospheric flow over the whole globe in real situations.

Changes continue to be made to the way in which physical and dynamical processes are incorporated, with a view to correcting observed deficiencies. For instance, integrations with all versions of the model tend to predict unrealistically high values of surface pressure near the poles, and trial modifications have been made to the way in which some terms are calculated in an attempt to correct this. Much attention has been given also to the way in which the complex processes near the earth's surface are formulated. The transfer of heat, water vapour and momentum between the surface layers and the free atmosphere is of fundamental importance, and effort has been devoted both to studying the characteristics of the surface layer and to determining the sensitivity of the model to their parametrization.

However, the main effort in this area during the year was directed to the various improvements which are needed before realistic simulations of long-period climate change are possible. Tests are being made of a revised formulation in which the surface moisture over land and the extent and depth of snow cover are themselves predicted by the model, instead of being imposed or estimated in too crude a fashion. These are important interactive mechanisms which affect evaporation and surface albedo. Also a new procedure is being tried to simulate solar and terrestrial radiation, using values of water-vapour concentration and of cloud generated during the integration. The response of cloud amount to changes in other parameters is a crucial factor in the study of climate. Some experiments have also been conducted with a model with lower horizontal resolution, which could be run more economically in long-period integrations.

In simulations of medium- and long-term atmospheric developments, it is desirable to replace the assumption of fixed sea surface temperatures which has generally been used, with a model of the oceans capable of responding realist-

ically to atmospheric conditions on fairly long time scales. As a first step in this direction a model of the oceanic mixed layer has been developed. Exploratory investigations using it have been conducted and it is being linked to an atmospheric general circulation model.

As stated above, all the research into the general circulation has been carried out with models which calculate values of meteorological variables at discrete grid points. Alternative methods of describing the state of a continuous fluid exists, and some effort has continued to be devoted to the use of the finite element approximation. This involves the use of simple functions to describe the variation of meteorological parameters, over small elements into which the area of integration is divided. The procedure has some advantages when applied to low-resolution general circulation experiments and it has been used in a number of investigations of this kind.

First GARP Global Experiment

Research into the general circulation is expected to benefit from the increased quantities of world-wide data that will be available during the FGGE, due to begin at the end of 1978. A small group has been assembled to run an experiment in real time, consisting of processing observations for the whole of the globe and incorporating them into a numerical predictive model. The normal network of observations will be enhanced during FGGE and additional reports are expected from floating buoys, constant-level balloons and satellites. A continuous integration using the 11-level general circulation model will be maintained, at least during special periods, with observations being assimilated directly into the model. This procedure, if successful, may in due course replace the present fixed-time analysis procedure.

In order to assess the adequacy of the observing system originally planned for FGGE, numerical experiments were conducted in which the above data-assimilation procedure was attempted, using simulated values of observations appropriate to such a network. As the density of observations is now expected to be lower, further comparative integrations have been carried out. These showed that the reports now expected to be available during FGGE should still enable global analyses and forecasts to be produced with significantly greater accuracy than could be achieved with the normal coverage. A report on these results was forwarded to the international working group concerned with making recommendations about the FGGE observational network.

Tropical meteorology

The GARP Atlantic Tropical Experiment (GATE), held in 1974, has furnished much material for further research in tropical meteorology. The Office, as Synoptic Scale Data Centre, was responsible for the checking, processing, and coding in standard format of all synoptic observations made during GATE. This task was completed during the year and magnetic tapes containing all these data, accompanied by comprehensive documentation, have been dispatched to the two World Data Centres in the USA and USSR and are now available to scientists throughout the world for research purposes. As well as providing observations virtually free of errors and in standard format, the data coverage is better than was achieved from broadcasts processed during GATE itself; this is particularly noticeable in the case of aircraft reports.

The analysis procedure designed for tropical areas, which was used during GATE, has been improved. Spatial correlations have been calculated from the GATE predictions, thus enabling better estimates to be made of the functions applied in the interpolation technique which forms the basis of this procedure. A real-time analysis for the whole tropical belt can now be produced and merged with that derived operationally in higher latitudes to give a single analysis covering the whole of the northern hemisphere. Such hemispheric analyses are being used for short-period forecasting experiments and also to investigate the possibility of monthly numerical forecasts.

Since it is not possible to experiment with the global atmosphere itself, the improvement of general circulation models of the atmosphere rests primarily on our ability to test them on the widest possible variety of atmospheric situations so that their shortcomings can be identified. The south-east Asian summer monsoon is one of the largest identifiable atmospheric systems; variations in its intensity have widespread implications. To help understand the dynamics of the monsoon and improve the simulation of it in general circulation models, experimental analyses and forecasts have been produced for a few actual monsoon situations. The forecasts were more successful than expected, particularly in respect of the movement of depressions in the Bay of Bengal, which have been identified as one of the main atmospheric systems for which a basic understanding of the underlying physics is still lacking. Examination of the predictions and the model's simulation of the monsoon continues.

Stratospheric research

Research has continued into the chemical and dynamical processes of the stratosphere, stimulated in particular by the requirement to investigate, on behalf of the Department of the Environment, the suggestion that chlorofluorocarbons (CFCs) injected into the atmosphere, for instance by aerosol sprays, might lead to a progressive weakening of the ozone layer. Experiments are in progress using a two-dimensional model of the atmosphere in which values of the meteorological parameters are averaged round a circle of latitude. This model has a resolution of 15° of latitude horizontally and a coarser version still is also being used. Very detailed resolution, however, is needed in the vertical, since many of the chemical processes are pressure- and temperature-dependent. In these models, the transport terms have been estimated in the light of results from a three-dimensional model, and also from other published data.

Advances in simulating chemical processes have been made in two ways. The number of species and the variety of reaction rates involved have been extended, in particular to include chlorine and its compounds. Also the model has been kept up-to-date by inserting the latest available estimates of reaction rates derived from laboratory experiments and by using current measurements of the minor atmospheric constituents. The two-dimensional models have been integrated, assuming chemical schemes of varying complexity. When the chemistry is simplified, very long integrations can be made; for instance simulation of the dispersion and photodissociation of CFCs, making various assumptions about their injection rate, have been taken to the year 1998.

In addition to this applied research, investigations into natural stratospheric processes continue. Those giving rise to sudden warmings are being studied, using a dynamical approach; in particular the exceptional warming during 1976–77 has been the subject of special attention.

Research related to long-range forecasting

The issue of 30-day forecasts at the beginning and mid-points of each calendar month continued throughout the year. The forecasts contain information on the expected temperature and rainfall over the United Kingdom, and the general character of the weather. Depending on the time of year an indication is also given of the likely incidence of frost, fog, snow, gales and thunderstorms. The format remained essentially unchanged from previous years. For each of ten districts of the United Kingdom, temperature is specified in terms of 5 categories and rainfall in terms of 3 categories, each of which, based on statistics for the 30 years 1941–70, is equally likely. The Press, radio and television gave the forecasts a good deal of publicity, but the maximum benefit from the modest level of success attained was probably derived by subscribers to the full published version of the forecast. This document, entitled *Monthly Weather Survey and Prospects*, provides, in addition to the full statement of the prospects, climatological information relevant to the application of the forecast and information on the weather of the previous month.

Following a substantial increase in demand for advice on the application of the forecasts to particular commercial and industrial operations a consultancy service was introduced in the autumn. Subscribers may consult the scientists responsible for the preparation of the long-range forecasts by telephone. The service is expected to be particularly useful to companies whose activities depend on the weather and for whom there is a significant return from even a small reduction in future uncertainty.

The long-range forecasts are derived largely from statistical considerations. By comparing what happened in the past with the current development of the atmosphere, the forecaster tries to deduce the most likely evolution of the atmospheric flow during the ensuing month or season. To help him, massive quantities of multifarious data have to be reduced to manageable proportions, the emphasis being on selecting those which experience has indicated to be most important. In this process of data reduction, computer-based methods of numerical analysis have proved particularly valuable; they have played an increasing part in the process of preparing long-range forecasts. Nevertheless no objective system is, as yet, capable of reproducing the skill of experienced meteorologists in assessing the available evidence, and human judgement continues to play an important part in formulating the monthly forecasts.

During the year, the archive of past weather data used for long-range weather forecasting has been further enlarged. Data from a variety of sources have been subjected to rigorous quality control before being added. Computer programs to improve access to the data and facilitate their use have been written. Verification of the forecasts and testing individually the various methods used in their preparation continued to receive a good deal of attention. No method proved clearly superior to any other and work continues to determine the optimum weight to be given to each.

Large-scale circulation and statistical studies

Research aimed at describing and understanding the long-term changes in the atmospheric flow by examination of the historical data continued. For example, when 30-day-average 500-mb heights in the Atlantic–European region are plotted against time they show periods when the long waves tend to persist,

interrupted by adjustment phases when the number of waves changes and the troughs and ridges move to new positions. One method by which these and other features of the large-scale circulation were introduced into the operational forecast procedure was by categorizing the hemispheric circulation in terms of indices, representing the surface and 500-mb flow, in areas of the northern hemisphere identified as specially significant in typifying the circulation as a whole. The sets of indices representing particular months have been used in selecting analogues for long-range prediction and in obtaining objective descriptions of the character of the weather in past years. The indices have also been used to look for possible variations in the atmospheric flow over the North Atlantic region related to the 'Quasi-Biennial Oscillation' (QBO), a well known reversal of airflow in the equatorial stratosphere which is repeated about every two years. Evidence appeared of a relative increase in the westerly flow in high latitudes over the Atlantic during the westerly phase of the QBO and a relative increase in the westerlies in lower latitudes during the easterly phase. The maximum northerly and southerly locations of the enhanced westerly stream over the Atlantic–European area appeared to occur shortly after the westerly and easterly maxima of the QBO. Associated with these movements there appears to be a progression then retrogression of the major long-wave troughs and ridges around the hemisphere. Averaging over the ten cycles of QBO observed since 1954, middle latitudes of the northern hemisphere appear to be rather warmer and drier during the westerly phase of the QBO than during the easterly phase.

Indices for individual days, similar to those used in the above study, but representing characteristics of the atmospheric flow over the British Isles and North Sea, have been used to study gales and maximum winds in these areas from 1881 onwards. Extreme-value analysis of annual maximum indices and annual maximum hourly winds over and around the British Isles was used to establish a relationship between wind speed and return period from which was derived a relationship between wave height and return period for the North Sea. This work was in support of a collaborative project with the offshore industry.

Work continues on a study of possible relationships between weather in the Atlantic–European area and flood levels of the River Nile, rainfall in the Indian monsoon, rainfall in the Sahel, and other events indicative of atmospheric interactions on a global scale. A study of droughts over north-east Brazil suggested that they were associated with the Southern Oscillation; this is a fluctuation of average sea-level pressure, with a period of 2–4 years, which occurs with opposite phase in the Indian and western Pacific Oceans and the eastern Pacific Ocean. The study has led to a re-examination of the association between the oscillation and weather events in middle latitudes.

Introduction of dynamical methods for long-range forecasting

During the year a small research group was set up to prepare the way for the introduction of dynamical models of the atmosphere in long-range forecasting. The model being used by the group, a 5-level 'general circulation model' has been developed in the Meteorological Office in the past few years. Some of its operating characteristics, the most recent development work on it and tests made to determine its response to changes in initial parameters such as radiation and the sea surface temperature are described on page 91. To prepare the way

for its introduction in operational forecasting, data sets to provide initial external parameters such as land characteristics and sea surface temperatures are being prepared. A scheme for the quality control and analysis of historical sea surface temperature data for the northern hemisphere was completed during the year, and work is in progress on producing a reliable semi-automatic hemispheric sea surface temperature analysis scheme for routine use.

Several investigations of the behaviour of the model using historical data have already been run, in particular to determine the extent to which it is capable of projecting synoptic and time-averaged features of the atmosphere. Forecasts based on past data are being analysed, each extending to 50 days, and centred on either December or July to represent the main extremes of temperature. Tests on other months of the year are planned. Assessment procedures are being designed both for these experimental forecasts and for the testing of the model when used in an operational mode.

Climatic change

The problem of climate variability and climatic change has continued to attract much public attention. In particular, there is growing concern about the possible impact of man's activities on the climate. Increased concentrations of carbon dioxide in the atmosphere, caused, it is believed, by the burning of fossil fuels, may give rise to significant climatic effects in the next few decades. Calculations made with simple atmospheric models but rather complete radiation-transfer equations confirmed that the radiation budget could be substantially affected by variations in carbon dioxide concentrations. The more detailed consequences on atmospheric motions need to be determined from general circulation model investigations.

Investigations were carried out using historical data to determine the extent to which the increase in carbon dioxide from pre-industrial times up to the present may have contributed to observed global temperature changes and to estimate its importance, relative to other factors, such as the incidence of volcanic dust or variations in solar radiation which also have been significant. The results indicated that carbon dioxide may have contributed to the rise of temperature observed during the first half of the twentieth century, but the analysis did not establish a significant relationship with the other variables considered. Indices representing the total extent of ice in polar regions and the average strength of the westerly winds in temperate latitudes were later added to the variables considered in the study. They differ from the other factors in being determined wholly or in part by the atmospheric circulation itself. The objective is to clarify how far they, as well as the more external factors, need to be taken into account in explaining the observed climatic fluctuations.

For many problems in climatic change the use of numerical models of the general circulation probably offers the most promising avenue of attack. Only limited experiments are possible at present. During 1977, for instance, further integrations were performed in which the intensity of solar radiation was set equal to that appropriate to the condition of the Earth's orbit 10 000 years ago. Sea surface temperatures were held at present values, and so the results of the experiment are thought to constitute a lower limit to the magnitude of the real effect of the changes in the orbit. The simulations produced temperatures in middle latitudes 2–3 °C higher than simulations using present-day radiation conditions. Particular attention is being given to the possible effects of increased

atmospheric carbon dioxide concentrations on the climate; as a preliminary to fuller investigations, using general circulation models, they have been studied in single-column representations of the atmosphere. The warming obtained by other investigators was reproduced, and the important feed-back mechanisms due to water vapour and cloud were investigated.

Special investigations

The Meteorological Office receives many enquiries about the weather and climatic conditions likely to be encountered at any place over the globe. Many of them, and particularly those related to industrial needs, require special investigations, in which the exercise of scientific judgement in appraising the indications from inadequate data may well be the prime requirement. Examples of the data provided for aviation enquiries during 1977 were: the maximum vertical velocities and extreme wind speeds likely to be encountered in Venezuela; rainfall intensities and spatial distribution of rainstorms over Europe and the North Atlantic; the amount of cloud at all levels in the atmosphere over Europe and the frequency of occasions when meteorological conditions would be suitable for carrying out aircraft noise tests. Advice was also given on a wide range of non-aviation subjects such as radio propagation, storm tide surges and air pollution.

Research in aviation meteorology has covered a wide field. The main emphasis has again been on low-level wind shear which has been responsible for a number of aircraft accidents in recent years. In collaboration with British Airways, a method of assessing the probability of shear being present and warning pilots to be prepared for it is being tested. Post-flight reports of the shear have been collected from the pilots and these, together with the data derived from flight-recorders, are being used to study the degree of success of the warning system.

Concern has been expressed by pilots that winds recorded by an anemometer at a central point on an aerodrome might not be representative of those at the touchdown or take-off points on the runway. Data collected at Heathrow have been analysed to assess the probability of the differences being unacceptably high. The Assistant Director (Special Investigations) is chairman of a working group set up by the Civil Aviation Authority (CAA) to study this problem. The group submitted its report to the CAA during the year.

Another area of increasing importance is the build-up of icing on helicopters. The Office was represented on a working group set up by the Ministry of Defence to make recommendations for a research and development program on this topic. The main task of the Office in the work that is planned is to define more precisely the probability of helicopters encountering atmospheric conditions (such as supercooled water, heavy snow etc.) which could cause an icing hazard. A study of the possibility of improving forecasting of icing has also been proposed.

Cumulonimbus clouds remain a major hazard to aviation. Work has been started with the aim of deriving from numerical forecast models the best index for forecasting their occurrence. Some work was also carried out for CAA to help them assess the extra work-load imposed on Air Traffic Control staff by pilots requesting deviations from their flight paths to avoid cumulonimbus clouds.

Airlines are still concerned about clear-air turbulence (CAT) which, if there

is no warning, can result in injuries to passengers and damage to the aircraft. A large volume of data was accumulated in 1976 from pilots' reports and it is being analysed for the purpose of deriving improved forecasting methods.

The Office has a representative on the CAA Civil Aircraft Airworthiness Data Recording Program's Special Events Working Panel which examines the outputs from flight-data recorders fitted to about 40 aircraft. The data are fed to a computer which is programmed to identify 'events' in which abnormal flight behaviour occurred and the Panel examines them to try to identify their cause. The work is of a continuing nature and the aim is to identify possible causes of accidents before they happen. Many of the events are caused by meteorological conditions. Recently the Office representative has reported on the probability that some events, suspected of being encounters with wake vortices, were caused by natural atmospheric turbulence. In another investigation, events in which too high an approach speed was recorded have been examined to see if they were associated with meteorological factors.

There is a continuing need for information on aviation climatology. The Office prepares and updates reports on climate in all parts of the world. Work has also continued on the preparation of descriptions and statistics of weather at aerodromes under British control.

There has been an increase in the number of enquiries connected with air pollution. Advice has also been given to some firms in the chemical industry to help them plan action to be taken in an emergency such as a serious leakage of gas.

A small team helps and encourages investigations carried out at outstations mainly in relation to problems involving local weather. Computer services for the provision of data and various forms of analysis as well as guidance and constructive criticism have been supplied to the investigators. This team also provides lectures and a computer service for students' projects at the Meteorological Office College and helps in the assessment of the projects.

The Office is occasionally asked to give advice on meteorological factors in aircraft accidents. The Assistant Director (Special Investigations) gave a series of lectures on this subject to an international audience at the Royal Institute of Technology in Stockholm.

General Activities of the Research Directorate

The Meteorological Office continued to work closely with a number of national and international bodies which are concerned with meteorological research. The Office provides representatives on a number of research-oriented committees of the Royal Society, the Natural Environment Research Council and the Science Research Council. In the international field, scientists from the Office serve on several working groups of the World Meteorological Organization and of the International Association of Meteorology and Atmospheric Physics.

The scientific research of the Office was reviewed by the Meteorological Research Committee and its subcommittees during the course of nine meetings. The Committee also advises on a number of small university research projects which are directly supported by the Meteorological Office; these number five in addition to six placed through the Gassiot Committee of the Royal Society.

During the year two members of university staffs worked in the Office as consultants for short periods, and one scientist from overseas worked for an extended period during which he was supported by his home institution.

Library, Publications, Archives and Cartographic Section

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by staff of the Office, but there is also a large demand for its services from universities, schools, commercial and industrial firms, and the general public.

The number of items classified and catalogued (which includes all relevant journal articles) continues to run at a high level. The number of loans increased somewhat compared with the previous year; in particular, the number of loans of published daily weather reports was very much greater, almost entirely on account of the demands of one university research project.

Following an assessment of the possibilities, a mini-computer dedicated to library use was installed during the summer. The development of computer programs to handle most of the work involved in recording accessions to the Library is at an advanced stage and it is hoped that the system will become operational early in 1978.

With the ending of blanket membership, by the Government, of the association of Special Libraries and Information Bureaux (ASLIB), independent membership was taken up by the Library. Co-operation with other Government libraries has been strengthened, especially with those within the Ministry of Defence. Advantage has been taken of the Selective Dissemination of Information (SDI) services available through the Defence Research Information Centre; retrospective searches have been carried out from the various data bases available and the fortnightly current awareness listings are proving useful.

The Library has taken up Corporate Membership of the American Meteorological Society and this, with the help of British Defence Staff in Washington, D.C., means that the Society's journals are available within a short time of publication. The Publishers Association agreed to the granting of a Library Licence, with its attendant privileges, in view of our services to outside users. However, in spite of the economies being made, the continuing steep increase in the cost of advanced scientific books and journals makes it difficult to fulfil the function of the Library within the present financial constraints.

The Editing Section remained responsible for preparing for printing most of the official publications of the Office, and co-operated closely with Her Majesty's Stationery Office in the maintenance of publishing standards. The continued refusal of a print union to handle computer tapes led to the decision to abandon the printing and publication of *British Rainfall* for 1969 and all subsequent years. This is particularly regrettable since it affects a publication that has been published as a continuous record from 1860, first by the British Rainfall Organization and then by the Meteorological Office.

Works published during the year are listed in Appendix III; they include the *Meteorological Magazine*, a monthly journal containing short scientific articles, reviews, and items of interest to meteorologists everywhere.

The distribution of publications, both official and commercial (scientific journals, textbooks, works of reference etc.) to the Office's many outstations, is under the control of the Publications Section, which is also responsible for the half-yearly issue of some 350 000 observation forms of all kinds to over 6000 reporting stations.

Meteorological observations in manuscript and other original documents and records are kept, in accordance with the Public Records Act, 1958, and the

Public Records (Scotland) Act, 1937, in special repositories (archives) in Bracknell, Edinburgh, and Belfast. The material in these archives is consulted by a large number of people, from both inside and outside the Office. During the year, for instance, over 940 loans were made from the archives at Bracknell.

The Cartographic Section prepares diagrams for Meteorological Office publications, for internal memoranda, and for papers contributed to scientific journals by members of the staff. It also prepares data-entry forms, exhibition displays, lecture and training viewfoils and slides as well as the many charts and diagrams, for various areas of the world, which are used for plotting meteorological observations.

Some statistics showing the extent of the work carried out by the Cartographic Section are given in Table XVI (page 105).

Professional Training

Policy on the professional and managerial training of Meteorological Office staff is determined by the Meteorological Office Training Board, under the chairmanship of the Director-General. Most professional training is carried out within the Office, either at the Meteorological Office College or at the Meteorological Office School of Technical Training, although some staff attend specialist courses elsewhere, usually for non-meteorological subjects. Close contact is maintained with neighbouring Colleges of Technology, the University of Reading, the British Council and the Royal Naval School of Meteorology and Oceanography.

The Meteorological Office College which is situated at Shinfield Park, south of Reading, is residential with accommodation for just over 100 students. It carries out training in basic meteorology at all levels as well as in forecasting, observing and related topics. It is well equipped for classroom teaching, for field-work and for instruction involving the analysis and use of meteorological charts. It has a cinema which seats 94, two lecture theatres and 13 classrooms, including one designed for tuition on instruments. An important part of many courses is the simulation of operational working conditions typical of Meteorological Office forecasting stations. For this purpose, current meteorological observations from many parts of the world, including those obtained from satellites, are received by teleprinter and facsimile. The College provides adequate room for field-work and for the siting of meteorological instruments. Students at the College are able to use its recreational facilities which include tennis courts, a squash court, rooms for table tennis and television and a bar.

The number of students completing courses at the College this year was 601. While most courses are designed for staff of the Meteorological Office, they are open to students from other meteorological services, provided that places are available. The numbers of Meteorological Office trainees and visiting students on each type of course this year are shown in Table XVII (page 105). The general pattern of courses has continued as in previous years. On the Scientific Officers' Course, for graduates with high honours, there were 10 students in the course that finished at the beginning of the year and 23 in the new course that started in October. Of these, 18 are from within the Meteorological Office, 3 from Malaysia and 2 from Hong Kong. The Applied Meteorology Course, which is designed for new entrants with university degrees or Higher National Certificates who are going to become support scientists or forecasters, gives

basic instruction in Meteorology at a somewhat lower level. This year, because there was no Meteorological Office requirement for forecasting training at this level, the course omitted those sections specifically dealing with practical weather forecasting. The course which finished at the beginning of the year had 15 students, including one each from Jordan, Switzerland and Sri Lanka. On the shorter course, which ran in the second half of 1977, there were 19 students including three from overseas (Sri Lanka, Jordan and Trinidad).

The other course concerned with basic training and forecasting is the Initial Forecasting Course. This year it catered for 15 students of ten nationalities. Only three were from the Meteorological Office. Two overseas students took the course as a preliminary to MSc studies at the University of Reading, and five others as an integral part of the University of Reading Sandwich Course which leads to an honours BSc in Meteorology. The Sandwich Course requires, as preliminary qualifications, GCE 'A' levels in mathematics and physics. It lasts for three and a half to four years and consists of alternating periods of academic and practical work. The latter is usually undertaken in a forecasting unit of the Meteorological Office. In this way students obtain both a good graduate qualification and training in some practical aspects of meteorology. This year, as last year, two members of the staff and four overseas students successfully completed the course.

A few years after their first course, forecasters normally return for an Advanced Forecasting Course to develop their knowledge and increase their professionalism. All those students on the course who are members of the Office are given an audition by the BBC. Most are Scientific Officers who are in the field for promotion to Higher Scientific Officers.

To implement the Training Board's policy of providing refresher courses for Higher Scientific Officers at intervals of 5 to 10 years, six Extension Courses were run this year. As well as revising synoptic meteorology and bringing it up to date, the course includes statistics and work on a project chosen by the student. This is designed to help forecasters conduct investigations at their own stations into the weather in the areas for which they are responsible.

Assistant Scientific Officers working at forecasting units normally begin their training on an Initial Assistants' Course lasting four weeks, during which they are taught the rudiments of plotting, coding and making observations. After about two years they attend the Advanced Assistants' Course which lasts six weeks and provides training in elementary meteorology, more advanced coding, pilot-balloon work and elementary instrument maintenance. This year only one Initial Course was necessary but seven Advanced Courses were held. Training is not finished when the student leaves the College; on-the-job training at outstations forms an essential part of the scheme.

The Station Supervisors' Course is designed for Scientific Officers just promoted from Assistant Scientific Officer who are expected to fill supervisory posts. It is both a refresher course in meteorology and meteorological observing and an introduction to the wider problems likely to be encountered by the promotees. Its purpose is akin to that of the Senior Meteorologists' Course which, at a higher level, aims to give Senior Scientific Officers, who may be either experienced forecasters or support scientists, a broad view of recent developments within the Meteorological Office and in the science of meteorology generally.

Except for the large intake of good honours graduates, the number of new

entrants into the Office was again small this year. At the College, however, this was largely offset by an increase in the variety of courses, especially for observers. Courses were held to train observers who man the Auxiliary Reporting and Climatological Stations in the UK, Air Traffic Control staff who make weather observations at some aerodromes, ground control staff of the British Airports Authority, senior observers of the Saudi Arabian Department of Meteorology and observers nominated by firms operating offshore installations in the North Sea.

Two newly designed courses for Meteorological Office staff who use the Office COSMOS computer system were both fully subscribed.

The College has also continued to be used by outside organizations for meetings and conferences with a meteorological relevance, including a Seminar for the European Centre for Medium-range Weather Forecasts, a Workshop on Water Quality for the European Region of the World Health Organization and the Meso-Meteorology Panel of the European Research Office of the US Army. Enquiries concerning this facility or any of the courses at the College should be addressed to the Principal, Meteorological Office College, Shinfield Park, Reading RG2 9AU.

Those joining the Meteorological Office as Assistant Scientific Officers are expected to improve their academic qualifications in scientific subjects by following part-time courses at technical colleges and colleges of further education. The number of staff released for such part-time study was 186 this year. A further 23 members of staff are taking Open University courses with assistance under the Civil Service Further Education Scheme. In addition 27 staff members began or continued a Block Release Higher National Certificate Course in mathematics, statistics and computing, which was started at the Reading College of Technology in 1974 for staff who do not live within easy reach of suitable colleges. This course consists of four six-week periods of full-time study, spread over two years, and during these periods the students live at Shinfield Park. Sixteen staff members took their final examination this year and 14 were successful; two were referred in one subject. During the year, 13 members of the staff were released, with pay, for full-time university studies or to attend Sandwich Courses. In addition, five have taken advantage of a scheme under which scientists can continue to work in the Office and study for a PhD degree under the joint supervision of the Office and a co-operating university.

Staff at the College kept abreast of developments in connection with the Technician Education Council's courses which will soon replace courses for City and Guilds of London and National Certificate examinations.

Table XVII shows the numbers of overseas students who have attended courses during the year at the Meteorological Office College. Most were sponsored by their governments, by WMO or by Overseas Development Aid. In addition, special arrangements were made for sponsored students to undergo on-the-job training in various branches of the Office; they came from several African countries, and from Afghanistan, Hong Kong and Poland, and studied subjects which included the use of marine data, the application of statistics to local forecasting problems, and the use of computers both in climatology and day-to-day synoptic work. Arrangements were also made for the training of five technicians from overseas in the maintenance of mechanical, electrical and electronic instruments; these programs are arranged in conjunction with the School of Technical Training at Beaufort Park, near Bracknell. Some training in basic skills was given at Training Services Agency Skillcentres.

Also, at the small radiosonde training school at Beaufort Park, five members of staff were trained to sound the upper air and measure winds aloft. All were destined to man those sounding stations overseas which form part of the UK contribution to World Weather Watch.

Some Headquarters and outstation staff of the Operational Requirements Branch (Met O 1) were trained in the new techniques needed with the Mk 3 radiosonde. Training was carried out at Aughton by staff from the Instrumentation Branch (Met O 16).

The Office continues to support a number of fellowships under the Voluntary Assistance Program (VAP) of the World Meteorological Organization. At the end of the year ten students were being assisted in this way. Students from the Bahamas, Ecuador and the Netherlands Antilles are taking first degrees in Meteorology at the University of Reading; MSc courses are being taken by students from Argentina, Barbados, Ghana, East Africa and Jordan; one student from Egypt is continuing his PhD at Reading. This year two VAP students gained second class honours in the University of Reading BSc examination and two others gained their MSc there.

K. H. STEWART
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library

Publications received:	
Daily weather reports	10 795
Books, journals etc.	8121
Slides and photographs	409
Individual books, pamphlets, articles etc. classified and catalogued	8822
Publications lent (excluding 48-hour loans):	
Daily weather reports	16 945
Books, journals etc.	17 670
Slides and photographs	7893
Number of exchange agreements	1115
Number of pages translated by Library translator	306
Russian 171, German 128, Spanish 1, French 6	
Number of pages translated by freelance translators	375
Russian 194, French 87, German 59, Japanese 13, Icelandic 11, Spanish 6, Czech 5	

Archives

Number of loans	941

Cartographic Section

Number of diagrams, maps and charts completed during year	2838
Number of reprographic jobs during year	390

TABLE XVII—TRAINING

The following figures give details of courses completed during 1977 at the Meteorological Office training establishments at Shinfield Park and Beaufort Park.

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Scientific Officers	1	23	10	0	10
Applied Meteorology	1	22	12	3	15
	1	11	16	3	19
Initial Forecasting	1	18	3	12	15
Advanced Forecasting	3	7	12	11	23
Extension Course	6	4	56	7	63
Senior Meteorologists	2	3	34	0	34
Meteorological Statistics	2	4	15	2	17
Tropical Meteorology	1	3	0	6	6
Mediterranean Meteorology	2	3	3	2	5
SO (Supervisors)	4	4	34	1	35
Auxiliary and Co-operating Observers	10	1	0	129	129
Initial Assistants	1	4	2	0	2
Advanced Assistants	7	6	63	5	68
Air Traffic Control staff	3	1	0	21	21
British Airports Authority staff	2	1	0	5	5
Oil-rig Observers	4	1	0	19	19
Nautical Officers	1	1	9	0	9
Initial Computer Users	1	2	12	0	12
Saudi Arabian Assistants	2	8	0	23	23

TABLE XVII (*continued*)

	Number of courses	Length in weeks	Met. O. staff	Others	Total
*ASO/RMT (Electronics)	1	28	9	2	11
ASO/RMT Equipment Course ...	1	19	9	2	11
New Equipment Course	4	1	15	2	17
	1	2	6	2	8
*Digital Computing Techniques ...	1	3	12	0	12
†Digital Computing Techniques ...	3	3	7	0	7
Radiosonde (Initial)	1	4	3	0	3
Radiosonde (Refresher)	2	1	2	0	2
Totals			344	257	601

*Courses carried out for Meteorological Office by RAF Support Command at RAF Sealand.
†Participation in courses carried out by RAF Support Command at RAF Sealand.

Students from the following territories attended courses which terminated during 1977.

	Number of students
Antigua	2
Bahamas...	1
Bahrain	2
Belgium	2
Belize	2
Cyprus	1
Ecuador	1
Ghana	1
Hong Kong	4
Isle of Man	1
Jersey	3
Jordan	2
Kuwait	2
Malaysia	3
Netherlands	3
Netherlands Antilles	1
Qatar	1
Saudi Arabia	23
Sri Lanka	2
Switzerland	4
Syria	3
Trinidad...	3
Uganda	2
Zambia	1
Total	70

ADMINISTRATION

Personnel Management

Introduction

Staff of the Meteorological Office serve at well over 100 locations in the UK and abroad. Numbers of staff at each vary between about 1200 in the Headquarters at Bracknell and 2 at units such as Port Meteorological Offices, thus posing a number of management problems very different from those in most other areas of the Civil Service. Personnel management for the great majority of staff, including all those in the scientific and technical grades, is undertaken centrally by the Secretary of the Meteorological Office and, under him, the Assistant Director and staff of the Personnel Management branch at Bracknell. In this way the career prospects of staff and the opportunities open to them do not depend on the size or location of their particular unit and, at the same time, the Office has maximum flexibility in meeting its varied staffing requirements. Some aspects of the personnel management work are outlined in the following paragraphs.

Manning

The manning of most posts in the Meteorological Office is the responsibility of the Personnel branch at Bracknell. Short-period detachments may be arranged by Principal Meteorological Officers at outstations, but all other movements are the responsibility of the manning sections. The majority of posts at outstations and a substantial number at Headquarters have to be manned 24 hours a day, 7 days a week without fail and this requires considerable planning and a high degree of mobility. All scientific and technical grades in the Office, including the basic grades of Assistant Scientific Officer and Radio (Meteorological) Technician, are mobile and the number of postings arranged during 1977 averaged about 25 a week. Movements are arranged after consultation with line managers and with the career-development section to ensure that, as far as possible, long-term as well as short-term needs are met. The preferences of individuals are also taken into account.

Career development

The aim of career development is essentially to make the most effective use of individual ability and to develop potential. Within the Meteorological Office the effort devoted to this has increased significantly in the last few years; career-development panels have been set up for senior and high-potential specialist staff, while a section of the Personnel Management Branch is concerned almost exclusively with monitoring and guiding the careers of other staff.

A vital part of any career-development program is a system of staff appraisal through which performance and progress can be carefully monitored. In common with other Government departments the Office operates an appraisal system with three components—written staff reports, job appraisal reviews and career interviews. The first two are annual responsibilities of line managers, while career interviews are given, less frequently, in the Personnel Branch. Full consultation and co-operation between the line managers and the appropriate

personnel management staff is encouraged at every stage. Training in the skills and techniques of staff reporting and appraisal interviewing has been given within the Office to a high proportion of the staff involved. There are clear signs that the Office is beginning to reap the benefit of the substantial effort devoted to the introduction and consolidation of these arrangements over the last five years or so.

Recruitment

The Personnel Management Branch is responsible for recruitment, in accordance with regulations laid down by the Civil Service Commission, to most grades for which the Office has a requirement, although at graduate level the Office is dependent on centralized recruitment undertaken by the Commission.

In 1977 recruitment requirements were met without undue difficulty. Staff joining the Office during the year included 15 honours graduates who were selected in a competition that attracted almost 500 applications. Recruitment to the Assistant Scientific Officer grades was resumed after an interval of two years and here too the number of applications substantially exceeded the number of vacancies. Temporary staff included eight College-based Sandwich Course students undergoing industrial training and seven vacation students who were employed for about two months in the summer. Two university lecturers worked briefly as vacation consultants in research branches.

Manpower planning

Continuous monitoring and forward planning is required to ensure that the Office is manned at an efficient level within agreed targets. During 1977 the age structure, recruitment, wastage and promotion patterns of the science grades over the past few years were critically examined and computer forecasts of future patterns were made. Although this work is still in its early stages, and the forecasts need further refining, some indication has already been given of the problems which could arise if early corrective action is not taken. This work will be continued in 1978 and extended to other groups of staff.

Staff numbers

At the end of 1977 the total number of posts of all grades was 3304, a decrease of 91 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary	1
Under Secretary	2
Science Group	
Chief Scientific Officer	1
Deputy Chief Scientific Officer	6
Senior Principal Scientific Officer	25
Principal Scientific Officer	108
Senior Scientific Officer	267
Higher Scientific Officer	496
Scientific Officer	494
Assistant Scientific Officer	892

Administration Group	
Assistant Secretary	1
Principal	1
Executive Grades	30
Clerical Grades	140
Marine Staff	
Marine Superintendent	1
Nautical Officer Grades	12
Ocean Weather Ships and Base	
Officers and non-industrial grades	49
Crew and industrial grades	49
Professional Engineer Staff	
Principal Professional and Technology Officer	1
Professional and Technology Officer Grade I	3
Professional and Technology Officer Grade II	5
Professional and Technology Officer Grade III	5
Professional and Technology Officer Grade IV	5
Technical and Signals Grades	289
Typing and miscellaneous non-industrial grades	136
Industrial employees	105
Locally entered staff and employees overseas	102

FINANCE

Except for the common services provided by other Government departments as part of their normal functions (i.e. accommodation by the Property Services Agency of the Department of the Environment, and stationery and office machinery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross expenditure of the Meteorological Office for the financial year 1977/78, including that on the common services, is estimated to be £29 364 000. Of the amount chargeable to Defence Votes (£28 764 000), £18 647 000 represents expenditure associated with staff and £10 117 000 on stores, communications and miscellaneous services. It is estimated that some £8 747 000 will be recovered from other Government departments and outside bodies for meteorological services, sale of meteorological equipment, etc.

A summary of estimated expenditure and receipts is given below.

EXPENDITURE

	£
1. Staff costs	18 647 000*
2. Equipment	7 281 000
3. Telecommunication network	931 000
4. Subscription and grants-in-aid to World Meteorological Organization including the Voluntary Assistance Program	467 000

5.	Research grants	35 000
6.	World Weather Watch stations overseas	160 000
7.	Fees for auxiliary observers	70 000
8.	UK contribution to the European Centre for Medium-range Weather Forecasts	452 000
9.	Assistance to the GARP Global Experiment	17 000
10.	Contribution to National Weather Radar Network	7000
11.	UK contribution to European network of Ocean Stations	5000
12.	Miscellaneous services and stores	692 000†
	Total	28 764 000‡

*Includes £940 000 for contract labour.
†Comprises conveyance of personnel and equipment, fuel, water and electricity, accommodation stores, clothing and postal expenses.
‡The common services element for the Property Services Agency and Her Majesty's Stationery Office, not included in this total, is taken to be £600 000.

RECEIPTS

		£
1.	For services to civil aviation	6 800 000
2.	Receipts from other repayment services	1 280 000*
3.	Sale and loan of meteorological equipment	249 000
4.	Secondments	200 000
5.	Miscellaneous receipts	83 000†
6.	Net receipts from other contributors to North Atlantic Ocean Stations Agreement for operation of the UK ocean weather ships	135 000‡
	Total	8 747 000

*Includes £600 000 from offshore oil operators.
†These receipts arise from movements of personnel (£52 000), occupation of accommodation at the Meteorological Office hostel (£12 000), and a contribution from the Department of Trade towards the cost of the New Hebrides upper-air station (£19 000).
‡This amount is the net result of offsetting the UK contribution to the North Atlantic Ocean Stations Agreement against a refund of the costs of operating the two UK ships. The operating costs are included in the expenditure figures.

A. C. HUGHES
Secretary,
Meteorological Office

INTERNATIONAL CO-OPERATION

The Seventh Session of the WMO Commission for Instruments and Methods of Observation was held in Hamburg from 1 to 12 August, preceded by a Technical Conference from 27 to 29 July. The United Kingdom delegation was led by Dr D. N. Axford, Assistant Director (Operational Instrumentation) and included Mr A. H. Hooper, Met O 1, and Lt Cdr R. A. Young, RN, Directorate of Naval Oceanography and Meteorology.

The Council of the European Centre for Medium-range Weather Forecasts (ECMWF) met in London on 30–31 March, 24 May and 8–9 November. The Director-General, Dr B. J. Mason, led the UK delegation except at the May meeting when Mr G. A. Corby, Director of Services, deputized for him. The delegation included Mr D. G. Harley, Assistant Director (International and Planning), and staff concerned with financial and personnel management in the Ministry of Defence. The major decision of the year was on the very powerful computer system to be acquired by the Centre. The Scientific Advisory Committee met in January with Mr J. S. Sawyer as Chairman. After his resignation the Council appointed Mr F. H. Bushby, Deputy Director (Forecasting Services), as a member of that Committee. The Communications Advisory Committee, with Dr R. L. Wiley (Met O 22) as a member, met from 25 to 27 May at the Meteorological Office College, Shinfield Park, and in September in Madrid. An ECMWF Seminar on 'Parametrization of the processes in the free atmosphere' was held at the College from 5 to 16 September and Mr R. S. Bell, Met O 11, took part.

Other external international meetings held at the College included a WHO European Region Workshop on Water Quality from 4 to 14 January and a meeting of the US Army's European Research Office Panel on Meso-Meteorology from 21 to 23 September. The latter was attended by Mr F. H. Bushby, Dr P. W. White, Assistant Director (Forecasting Research), and Dr K. M. Carpenter, Met O 11.

The Western European Directors of Meteorological Services, including Dr B. J. Mason, held their 7th informal meeting at Palma, Majorca on 20–21 April. Dr B. J. Mason, accompanied by Mr D. G. Harley, had a brief meeting in Sciez, France on 5 June with the Heads of the Meteorological Services of Australia, France, Federal Republic of Germany, Sweden and USA.

Work continued on meteorological projects for European Co-operation in Science and Technology (COST). The Project 43 Technical Committee on Oceanography and Meteorology met in Brussels in April; Dr D. N. Axford participated. Two regional sub-groups of Project 43 met in Bergen in September and were attended by Mr M. J. Kerley, Met O 16. Mr G. A. Clift, Met O 16, attended the meeting of the Project 72 Technical Committee on Standardization of Instruments in Brussels in December.

There was much activity in furtherance of the Global Atmospheric Research Program (GARP). In support of the First GARP Global Experiment (FGGE), Dr P. Ryder, Assistant Director (Cloud Physics), took part in a WMO International Evaluation Board in Geneva in January to assess proposals for the NAVAID wind-finding system to be used on ships in the tropics. Mr G. A. Corby represented the UK at meetings of the WMO Inter-governmental Panel on FGGE in Geneva in February and December. In April a FGGE Research

Co-ordination Conference in Stockholm was attended by Mr F. H. Bushby. The first planning meeting for the GARP Mountain Sub-program was held in Venice from 24 to 29 September and was attended by Dr R. Hide, Head of Met O 21, and Dr P. W. White. Informal planning meetings were held at De Bilt, Netherlands from 14 to 16 November on Non-real Time Aircraft Data Collection, and at Norrköping, Sweden from 21 to 25 November to co-ordinate evaluation and end-to-end tests of the FGGE Data Management System. Both were attended by Mr M. V. Jones, Met O 12. To assist in planning the data management for the Monsoon Experiment (MONEX), which is to be run as a regional experiment in association with FGGE in 1979, Mr E. A. Spackman, Met O 3, visited New Delhi and Kuala Lumpur during December as a Consultant for WMO.

Studies of air pollution problems continued in several forms. Dr F. B. Smith, Assistant Director (Boundary Layer Research), attended the final meeting of the OECD Steering Group on the Long-range Transport of Air Pollution in Paris on 30–31 March; a working group meeting of the European Car Manufacturers' Study of Pollution in Cities, held in Turin on 14–15 July; an International Symposium on Sulphur in the Atmosphere, Dubrovnik, from 7 to 15 September; and a working group meeting under the Anglo-Soviet Joint Agreement on Air Pollution Control, Moscow, from 25 September to 2 October.

A planning meeting for the Economic Commission for Europe's program on Long-range Transmission of Air Pollutants in Europe, held in Geneva from 13 to 16 September, was attended by Mr R. D. Hunt, Met O 14.

Other WMO meetings, or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, were as follows:

Subject	*Place and date*	*Attended by*
Co-ordination on Geo-stationary Meteorological Satellites	Geneva January	Mr J. Morgan (Met O 19)
Ad hoc meeting of representatives of the JOC Working Group on Numerical Experimentation	Bracknell March	Dr R. A. Bromley (Met O 20)
15th Session of JOC Working Group on Numerical Experimentation	Stockholm April	Mr F. H. Bushby, Deputy Director (Forecasting Services)
5th Session of CBS Working Group on Codes	Geneva April	Mr P. Menmuir (Met O 6)
JOC/SCOR Study Conference on General Circulation Models of the Ocean and their Relation to Climate	Helsinki May	Dr P. R. Rowntree (Met O 20)
Executive Committee Panel on the Voluntary Assistance Program	Geneva June	Mr D. G. Harley, Assistant Director (International and Planning)
Four-Centres Telecommunications Meeting	Offenbach June	Mr D. McNaughton, Assistant Director (Telecommunications) Mr C. E. Goodison (Met O 5)
2nd Session of NAOS Board	Geneva July, October	Dr N. E. Rider, Deputy Director (Observational Services)
International Intercomparison of Dobson Spectrophotometers at NOAA Environmental Research Laboratory	Boulder, Colorado August	Mr J. H. Convery (Met O 19)
Technical Conference on the Energetics of the Tropical Atmosphere	Tashkent, USSR September	Mr A. Gilchrist, Deputy Director (Dynamical Research)
CoSAMC Advisory Working Group	Geneva October	Dr N. E. Rider, Deputy Director (Observational Services)
Informal Meeting on the World Climate Program	Geneva October	Mr A. Gilchrist, Deputy Director (Dynamical Research)

Subject	*Place and date*	*Attended by*
WMO/FAO Technical Conference on the Potential Economic Benefits of Agricultural Meteorology	Rome October	Mr C. V. Smith (Met O 8)
WMO/UNEP Ozone Meeting	Geneva November	Dr R. J. Murgatroyd (Met O 20)
CMM Working Group on Marine Climatology	Geneva November	Mr D. J. Painting (Met O 3)
CBS Working Group on Global Telecommunication System	Geneva November–December	Mr D. McNaughton, Assistant Director (Telecommunications) Mr B. W. Anderson (Met O 5)
Technical Conference on GATE Data Utilization	Cairo December	Mr P. Graystone, Assistant Director (Dynamical Climatology)

Attendances not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad were as follows:

Establishment of new Dobson Spectrophotometer Ozone Station	St Helena January	Mr J. Convery (Met O 19)
AAFCE Meteorological Working Group	Ramstein, West Germany January	Mr D. Forsdyke (Met O 6) Mr E. Cayhill (Met O 6)
SHARE (USA/IBM Users' Group) European Association Winter Project Meeting	Lyngby, Denmark January	Mr E. J. English (Met O 12)
EEC Solar Radiation Data	Brussels February	Mr C. V. Smith (Met O 1)
	Rome June	Mr B. R. May (Met O 1)
	Brussels September	
Meetings of Mariner, Jupiter, Saturn Imaging Team	Los Angeles February, March, April, June	Dr G. E. Hunt (Met O 19)
Meetings of ESA Solar System Working Group	Bern February	Dr G. E. Hunt (Met O 19)
	Paris March	
	Trieste May	
Meeting of CNRS Scientific Committee related to Radiative and Thermal Balance of the Atmosphere	Paris February	Dr P. R. Jonas (Met O 21)
NATO MCMG Working Group on Weather Communications	Brussels February, August	Mr C. E. Goodison (Met O 5)
ESA METEOSAT Dissemination Schedules Meeting	Paris February	Dr K. H. Stewart, Director of Research
ESA METEOSAT Scientific, Technical and Advisory Group	Paris February, April, September	Dr K. H. Stewart, Director of Research
International Symposium on Monsoons	New Delhi March	Mr D. B. Shaw (Met O 20)
Seminar and Meeting on Tripartite Agreement on Stratospheric Monitoring	Paris March	Dr R. J. Murgatroyd (Met O 20) Mr P. Graystone, Assistant Director (Dynamical Climatology)
	London June	Dr R. J. Murgatroyd (Met O 20)
Meetings of ESA Scientific Consultants' Group on SEOCS	Paris March	Dr G. E. Hunt (Met O 19)
	Noordwijk, The Netherlands May	

Subject	*Place and date*	*Attended by*
ESA Meetings concerning METEOSAT Data Processing	Darmstadt March, October Paris April	Mr D. E. Miller, Assistant Director (High Atmosphere) Dr K. H. Stewart, Director of Research Mr D. E. Miller, Assistant Director (High Atmosphere)
ESA Minimetsat Study	Paris March	Dr K. H. Stewart, Director of Research Mr D. E. Miller, Assistant Director (High Atmosphere)
NATO MCMG Working Group on Weather Plans and Weather Communications	Copenhagen March	Mr D. W. Tann (Met O 6) Mr C. E. Goodison (Met O 5)
ESA METEOSAT Program Board Working Group on Space Meteorology	Paris March, September	Dr K. H. Stewart, Director of Research
Visits to NOAA and NESS, Washington, D.C. and RCA, Princeton, N.J.	USA March August	Mr G. C. Bridge (Met O 19) Mr D. R. Pick (Met O 19)
25th Meeting of AFCENT Meteorological Committee	Cologne April	Mr D. Forsdyke (Met O 6) Mr E. Cayhill (Met O 6)
URSI Symposium on Electronic Wave Propagation in Non-ionized Media	La Boule, France April	Mr J. Crabtree (Met O 9)
NATO MCMG Working Group Sub-group VII	Brussels May	Mr F. Singleton (Met O 2)
ISO Committee on Wind Loading	Paris May	Mr R. H. Collingbourne (Met O 3)
NATO Army Armaments Group	Brussels May, September	Mr H. A. Douglas (Met O 16)
Co-ordination meeting for an International Civil Defence Exercise	Banbury May	Mr D. W. Tann (Met O 6) Mr P. G. Rackliff (Met O 6)
SHAPE Meteorological Committee	Wahn, West Germany May	Mr D. W. Tann (Met O 6) Mr C. Haworth (Met O 13) Mr D. Forsdyke (Met O 6)
Presentation by ESA of study on 'Radiation Balance Measurements with Micro-accelerometer'	Paris May	Dr K. H. Stewart, Director of Research
NATO AGARD Fluid Dynamics Panel	Copenhagen May	Dr R. Hide (Head of Met O 21)
AFCENT Sub-group on Low Flying	Wahn, West Germany June	Mr E. Cayhill (Met O 6)
34th Meeting of NATO MCMG	Traben-Trarbach, West Germany June	Mr I. J. W. Pothecary, Assistant Director (Defence Services) Mr D. W. Tann (Met O 6) Mr C. E. Goodison (Met O 5)
2nd ICAO Meteorological Services Meeting	Paris June	Mr C. H. Hinkel (Met O 7)
Spring Annual Meeting of the American Geophysical Union	Washington, D.C. June	Dr R. Hide (Head of Met O 21)
Conference on Animal Production from Temperate Grasslands	Dublin June	Mr W. R. Sparks (Met O 8)
20th COSPAR Meeting	Tel Aviv June	Dr N. E. Rider, Deputy Director (Observational Services)
Visit to NOAA and NESS, Washington, D.C. and RCA, Astro-Electronics, Princeton, N.J.	USA June	Mr G. C. Bridge (Met O 19)
Marcel Nicolet Symposium	Belfast July	Mr P. Graystone, Assistant Director (Dynamical Climatology) Mr K. S. Groves (Met O 15)
NATO Workshop on Ecotoxicology	Guildford July	Mr P. Graystone, Assistant Director (Dynamical Climatology)
ESA METEOSAT Flight Readiness Review	Toulouse July	Dr K. H. Stewart, Director of Research

Subject	*Place and date*	*Attended by*
US Central GATE Workshop	Boulder, Col. August	Dr K. L. Webber (Met O 14) Dr P. R. Rowntree (Met O 20)
Austrian Solar and Space Agency Summer School on Satellite Meteorology	Alpbach August	Mr R. W. Lunnon (Met O 19)
NORSWAM Technical Advisory Group	Hamburg September	Dr A. J. Gadd (Met O 2) Mr B. W. Golding (Met O 2)
NATO Symposium on Turbulent Fluxes through the Sea Surface, Wave Dynamics and Prediction	Marseilles September	Mr B. W. Golding (Met O 2)
Visit to the West German Meteorological Service	Offenbach September	Dr B. J. Mason, Director-General
IMCO Safety on Navigation Sub-committee	London September	Captain G. A. White, Marine Superintendent
9th Antarctic Treaty Consultative Meeting	London September	Mr D. G. Harley, Assistant Director (International and Planning)
A course of lectures at the Royal Institute of Technology, Institute of Aviation Safety, on Aviation Accident Prevention Investigative Techniques	Stockholm September	Mr D. R. Grant, Assistant Director (Special Investigations)
NATO MCMG *ad hoc* Sub-group Meeting between Chairman and Secretary of MCMG	Brussels September	Mr I. J. W. Pothecary, Assistant Director (Defence Services)
9th International Conference on Atmospheric Aerosols, Condensation and Ice Nuclei	Galway September	Mr P. Goldsmith, Deputy Director (Physical Research) Dr P. Ryder, Assistant Director (Cloud Physics)
1st Meeting of the Meteorological Panel for Operations in the North Sea and Adjacent Waters	Amsterdam September	Mr R. M. Morris (Met O 7)
European Geophysical Society Assembly	Munich September	Dr R. Hide (Head of Met O 21)
European Organization for the Safety of Air Navigation	Brussels October	Dr D. A. Forrester (Met O 2)
NOAA (NESS and NWS) to study operational use of satellite data and imagery	Washington, D.C. and Boston, Mass. October	Mr P. R. S. Salter (Met O 2)
EEC Solar Radiation Data Acquisition Group	Carpentras, France October	Mr B. R. May (Met O 1)
IEA Solar Energy Program Task Groups	Ispra, Italy October	Mr B. R. May (Met O 1)
ISO Sub-committee on Environmental and Operating Conditions for Aircraft Equipment	London October	Mr J. Crabtree (Met O 9)
NATO MCMG Working Group on Weather Plans and Weather Communications	Rome October	Mr C. E. Goodison (Met O 5) Mr D. W. Tann (Met O 6) Mr C. Haworth (Met O 13)
International Safety at Sea Symposium	London October	Captain G. A. White, Marine Superintendent
Meeting on Climatic Change and European Agriculture	Wye College, Kent October	Miss M. G. Roy (Met O 8)
Meeting of Experiment Team for NASA Stratospheric Aerosol and Gas Experiment	Hampton, N. J. November	Mr D. E. Miller, Assistant Director (High Atmosphere)
Visit to NOAA/NESS and NASA, Washington, D.C. and RCA, Princeton, N.J. in connection with the spacecraft integration for TIROS-N	USA November, December	Mr G. P. Carruthers (Met O 19)
3rd International Symposium on Computing Methods in Science and Engineering	Versailles December	Dr M. J. P. Cullen (Met O 11)
Joint IUTAM/IUGG Symposium on Monsoon Dynamics	New Delhi December	Mr A. Gilchrist, Deputy Director (Dynamical Research)

The following staff were released by the Office during 1977 for service with international and other organizations:

Mr J. Morgan	Principal Scientific Officer	European Space Agency
Mr C. Haworth	Principal Scientific Officer	SHAPE
Mr E. R. Thomas	Senior Scientific Officer	New Hebrides
Mr E. W. Smith	Higher Scientific Officer	International Aeradio Limited
Mr B. P. Norris	Higher Scientific Officer	ECMWF, Bracknell
Mr C. S. Clarke	Higher Scientific Officer	ECMWF, Bracknell
Mr C. A. Brimacombe	Higher Scientific Officer	European Space Agency
Mr S. Nicholls	Higher Scientific Officer	NCAR, Boulder, Colorado
Mr J. R. Maxfield	Higher Scientific Officer	Seychelles
Mr W. K. Young	Scientific Officer	WMO, Geneva
Mr P. J. R. Smith	Telecommunication Technical Officer III	Seychelles
Mr J. A. Nelson	Telecommunication Technical Officer III	New Hebrides
Mr G. C. Turner	Assistant Scientific Officer	Royal Society, Aldabra

Staff returning from international and other secondment appointments were:

Mr K. Bryant	Principal Scientific Officer	SHAPE
Mr M. W. Stubbs	Principal Scientific Officer	WMO, Geneva
Mr W. M. Longworth	Higher Scientific Officer	Seychelles
Mr C. W. Brookes	Telecommunication Technical Officer III	Seychelles
Mr G. C. M. Taylor	Assistant Scientific Officer	Royal Society, Aldabra

STAFF HONOURS AND DISTINCTIONS

Mr C. L. Edwards and Mr F. G. E. Allison were both awarded the Imperial Service Medal.

The L. G. Groves Memorial Prize for Meteorology was awarded to Dr A. J. Gadd and Dr S. J. Caughey received the L. G. Groves Second Memorial Award.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

ADAMS, R. J., Ph.D. and SEAGER, JUDITH M.; Agrometeorological use of the synoptic data bank in plant disease warning services. *Met Mag, London,* **106,** 1977, pp. 112–116.

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APPENDIX II

A SELECTION OF LECTURES AND BROADCASTS GIVEN BY MEMBERS OF STAFF

ADAMS, R. J., Ph.D.

The meteorological aspects of assessing water requirements. *MAFF/ADAS Regional Conference on Irrigation of Vegetables, Great Yarmouth.* 1 January.

ALLEN, J. J.

Meteorology for yachtsmen. *Two courses* (5 *lectures*), *Adult Further Education Centres, Guildford and South Farnborough.* January–March.

BARNARD, J. and HOUGHTON, D. M., M.Sc., D.I.C.

Understanding your weather forecast. *Petroleum Industry Training Board Course, Aberdeen.* 29 March.

BENNETTS, D. A., Ph.D.

Cloud dynamics. *Royal Meteorological Society Review Meeting on 'Cloud Physics Research', Imperial College, London.* 14 December.

BEST, K. E. and SCOTT, J.

The weather. *A series of weekly programs for schools, BBC TV.* 23 September to 2 December.

BLACKALL, R. M., B.Sc.

Mountain weather. *Royal Meteorological Society Field Course, Betws-y-Coed, Gwynedd.* 3–10 August.

BORRETT, P. D., B.Sc.

The weather. *Phone-in program, Radio Oxford.* 9 August. *Participation in farming program, BBC Radio 4.* 23 October.

BROWNING, K. A., Ph.D., D.I.C.

Radar studies of rainfall. *Department of Geography, University of Bristol.* 18 February.

The use of radar for the measurement and short-period forecasting of rain. *Department of Geophysics, University of Reading.* 4 March.

Radar techniques for probing the atmosphere. *European Research Office* (*US Army*) *Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 23 September.

The role of radar in the short-period weather forecasting pilot project. *Royal Meteorological Society Meeting of the Surface-based Remote Sensing Specialist Group, Appleton Laboratory, Slough.* 8 November.

CARPENTER, K. M., Ph.D.

Surface exchanges in a mesoscale numerical model of the atmosphere. *Royal Meteorological Society Summer Meeting, University of Lancaster.* 22 July.

Application of a non-hydrostatic model to a real sea-breeze situation. *European Research Office* (*US Army*) *Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 21 September.

Surface exchanges and the boundary layer in a mesoscale model. *Royal Meteorological Society Specialist Group on Dynamical Problems, Meteorological Office College, Shinfield Park.* 27 October.

CARSON, D. J., Ph.D.

The atmospheric boundary layer and its parametrization in large-scale models. *Royal Meteorological Society Specialist Group on Dynamical Problems, Meteorological Office College, Shinfield Park.* 27 October.

CATON, P. G. F., Ph.D.

Availability of wind and solar radiation in the United Kingdom. *Conference on Ambient Energy and Building Design, University of Nottingham.* 21 April.

CAUGHEY, S. J., Ph.D.

Direct estimation of structure parameters in the atmospheric boundary layer. *Conference on Acoustic Sounding, organized by the Institute of Acoustics, Loughborough University of Technology.* 11 May.

Acoustic Doppler sounding of the atmospheric boundary layer. *Royal Meteorological Society Meeting of the Surface-based Remote Sensing Specialist Group, Birmingham University.* 12 July.

Acoustic sounding—a review. *European Research Office (US Army) Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 23 September.

CLOUGH, S. A., Ph.D.

Two-dimensional model studies of stratospheric chemistry. *United Kingdom Geophysical Assembly, Edinburgh.* 6 April.

COCHRANE, J.

Meteorology and horticulture. *Kirdford Growers, West Sussex.* 20 January.

COLLIER, C. G., B.Sc., A.R.C.S.

Demonstration of a radar rainfall processing, transmission and display system. *British Association for the Advancement of Science, Science and Technology Fair, Worcester.* 1–5 April.

Demonstration of some of the work of the Meteorological Office. *Royal Society Silver Jubilee Display, London.* 20–22 June.

Radar measurement of rainfall. *Royal Meteorological Society Discussion Meeting on 'The Measurement and Analysis of Rainfall', Imperial College, London.* 16 November.

CREASE, B. A., M.Sc.

Acoustic sounding of radiation fog. *Conference on Acoustic Sounding, organized by the Institute of Acoustics, Loughborough University of Technology.* 11 May.

CULLEN, M. J. P., Ph.D.

The application of finite element methods to non-linear problems as met in weather forecasting. *Institut de Recherches d'Informatique et d'Automatique, Versailles.* 5–9 December.

DAVIS, T. M. and OGDEN, R. J., B.Sc.

The weather. *Phone-in program, 'Open Line', BBC Wales.* 25 May.

DEEKS, P. H. G.

Weather and sailing. *London Sailing Project, HMS President.* 13 February.

Collection of data and production of forecasts. *Royal Yacht Association Course for Yacht-masters' Certificate, Merton Technical College, Surrey.* 29 March.

DENT, L., B.Sc.

Forecasting methods. *Six lectures to the M.Sc. course, Department of Geophysics, University of Reading.* March–May.

Aviation meteorology. *Eight lectures to the course for aircraft accident investigators, Cranfield Institute of Technology, Beds.* 25 April to 1 July.

DICKINSON, A., Ph.D.

Four-dimensional data assimilation used in the 10-level model. *Royal Meteorological Society Specialist Group on Dynamical Problems, University of Reading.* 10 February.

EMERY, P. F.

The weather.

Recorded talk, Radio Cleveland. 13 January.

Recorded talk for farming program, Radio Newcastle. 18 February.

Interview on farming program, Radio Carlisle. 13 July.

The work of the Newcastle Weather Centre. *Talk on BBC TV 'Look North' program.* 13 and 27 October.

The weekend temperature forecasting service.

Interview on Radio Cleveland. 27 October.

Interview on Radio Metropolitan. 28 October.

Interview on Radio Newcastle. 4 November.

The weather. *Lecture at University of Newcastle.* 11 November.

White Christmases. *Talks on Radio Newcastle, Radio Tees, Radio Cleveland and Radio Metropolitan.* 21, 22 and 23 December.

FISH, M. J.
Weather forecasting and financial benefits. *Recorded talk for schools, BBC Radio 4.* 29 April.
The weather. *Talk for schools, BBC Radio 4.* 2 June.
The gales in mid-November. *Contribution to 'Pebble Mill at One' program, BBC TV.* 15 November.

FOLLAND, C. K., B.Sc., M.Inst.P.
Meteorological aspects of drainage design. *Spring courses held by PTRC Education and Research Services Ltd, London.* 23 May.
Rainfall investigations. *Hydrological Group of the Institute of Civil Engineers, Bracknell.* 27 September.
Flood studies in the UK. *Royal Meteorological Society Discussion Meeting on 'The Measurement and Analysis of Rainfall', Imperial College, London.* 16 November.

FRANCIS, P. E., Ph.D.
Modelling the moisture balance under spring barley using meteorological data and soil parameters. *Royal Meteorological Society Summer Meeting, University of Lancaster.* 22 July.
The climate of upland Britain. *Symposium on the Future of Upland Britain, University of Reading.* 19–22 September.

GADD, A. J., Ph.D.
Computer weather prediction. *Public lectures at University of East Anglia.* 28 and 29 April.
Analysis of maximum significant wave-height data for selected North Sea storms (text by A. F. Jenkinson, M.A., I.S.O.). *Discussion of NORSWAM Papers, Hamburg.* 9 September.

GILES, W. G.
Weather in the Ekofisk area. *Interview on BBC TV 'Nationwide' program.* 25 April.

GILCHRIST, A., M.A.
Numerical simulation of the south-west monsoon. *Joint IUTAM/IUGG Symposium on Monsoon Dynamics, New Delhi, India.* 5–9 December.

GOLDING, B. W., B.Sc.
Forecasting waves and swell—the Meteorological Office model. *Joint Seminar, Royal Meteorological Society/Society for Underwater Technology, London.* 10 March.
A depth-dependent wave model for operational forecasting. *NATO Symposium on Turbulent Fluxes through the Sea Surface, Wave Dynamics and Prediction, Marseilles.* 16 September.

GOLDSMITH, P., M.A.
Weather modification—intentional. *University of Reading.* 24 February.
Inadvertent weather modification. *University of Reading.* 10 March.
Freons and the ozone layer. *Pharmacology Department, Brighton Polytechnic.* 27 April.
Three lectures: (1) On the reliability and representativity of measurements of the chemical components of air and rain-water, (2) The possible influence of photochemical pollution on visibility in the United Kingdom, (3) The scavenging of particulates from the atmosphere by rain and clouds. *Ninth International Conference on Atmospheric Aerosols, Galway.* 21–27 September.

GRANT, D. R., B.Sc.
Aviation accident prevention investigative techniques. *A course of lectures at the Royal Institute of Technology, Institute of Aviation Safety, Stockholm.* 26–30 September.

HARROLD, T. W., Ph.D., D.I.C.
Instrumentation of offshore weather stations. *Joint Seminar, Royal Meteorological Society/Society for Underwater Technology, London.* 10 March.

HAYES, F., B.A.
A career in meteorology. *Wellington College, Crowthorne, Berks.* 4 July.
Demonstration of modern aids to forecasting. *Royal Society Silver Jubilee Display, London.* 20–22 June.

HIDE, R., Sc.D., F.R.S.
Motions in planetary atmospheres.
Institute of Physics, Liverpool. 24 January.
Department of Radio-astronomy, Jodrell Bank, University of Manchester. 26 January.
Department of Physics, Queen Mary College, London. 3 March.
University of Mainz, Federal Republic of Germany. 8 December.
Instabilities in rotating fluids. *Department of Mathematics, University of Reading.* 2 February.
Western boundary currents and detached shear layers in rotating fluids.
United Kingdom Geophysical Assembly, Edinburgh. 14 April.
Non-linear interaction of baroclinic waves.
United Kingdom Geophysical Assembly, Edinburgh. 13 April.
American Geophysical Union, Washington, D.C. 31 May.
Geophysical Fluid Dynamics Laboratory, Princeton University, N.J. 13 June.
Planetary magnetic fields. *University of Newcastle upon Tyne.* 8 July.
Topographic effects in rotating fluids. *European Geophysical Society, Munich.* 7 September.
Geomagnetism and structure of the earth's interior. *International Theoretical Physics Institute, Trieste, Italy.* 2 November.
Experiments with rotating fluids. *University of Newcastle upon Tyne.* 2 December.

HINKEL, C. H., B.Sc.
Forecasting services for pilots. *Royal Meteorological Society Discussion Meeting on 'Meteorology and Light Aircraft', London.* 15 October.

HIRST, N.
Weather in history. *Strathclyde Regional Council, Schools' Adventure Group.* 28 March.

HOPKINS, J. S., B.Sc.
Lectures on clouds, rain and snow, and on meteorological information for planning. *Royal Meteorological Society course on 'Meteorology for Civil Engineering and Building', University of Reading.* 24 March.
Collection, quality control and application of climatological data. *Quality and Reliability Group of Electronic Engineering Firms, Edinburgh.* 19 October.
Weather data for planning and design. *Department of Meteorology, University of Edinburgh.* 17 November.
Meteorological data for hydrology. *University of Strathclyde.* 25 November.

HOUGHTON, D. M., M.Sc., D.I.C.
The ship routeing service. *Recorded interview for the Canadian Broadcasting Service.* 27 January.
Application of weather forecasts to offshore operations. *Joint Seminar, Royal Meteorological Society/Society for Underwater Technology, London.* 10 March.
Weather and weather forecasting. *Four lectures at Atlantic College, Llantwit Major, South Glamorgan.* 16 March.
Weather and weather forecasting. *Interview on Thames TV.* 30 March.
Weather outlook—forecasting. *Contribution to program, BBC Radio 3.* 7 April.
Weather outlook—economic benefits of forecasts. *Contribution to program, BBC Radio 3.* 14 April.
Weather for yacht racing. *Admiral's Cup Training Course, Cowes.* 9 July.
Weather forecasting. *Talk on BBC Radio 4.* 24 August.
Calm or stormy—managing a Weather Centre. *British Institute of Management, Reading.* 1 December.

HULL, A. H.
The work of the London Weather Centre. *Branch of the Pharmaceutical Society of Great Britain, Barnet, Herts.* 11 January.

HUNT, G. E., Ph.D.
Contribution to BBC TV program 'Sky at Night' concerning Mars and the major planets. 13 April.
Planetary atmospheres—emerging perspective. *United Kingdom Geophysical Assembly, Edinburgh.* 14 April.
Satellites of Mars—100 years on. *Royal Astronomical Society, London.* 13 May.
Two lectures: (1) Future missions to the major planets, (2) Exploration of the Earth's atmosphere during the next decade. *European Space Agency Long-term Planning Meeting, Trieste, Italy.* 16 May.
Contribution to BBC TV program 'Sky at Night' concerning Uranus. 10 June.

INGHAM, B.
Heat losses and shelter: their effects on glasshouses and plastic structures. *Gloucester Society of Nurserymen.* 26 January.
Weather of the last two years and the likelihood of recurrence. *Fruit Irrigation Study Group, Bristol.* 30 March.

JAMES, D. G., Ph.D.
The work of the Meteorological Research Flight. *Scottish Centre of the Royal Meteorological Society, Edinburgh.* 11 November.
JAMES, I. N., Ph.D.
Taylor columns: transient effects around high bumps. *British Theoretical Mechanics Colloquium, University of Hull.* 31 March.
Side-band instability of baroclinic waves. *Woods Hole Oceanographic Institute, Massachusetts.* 10 November.
JENKINSON, A. F., M.A., I.S.O.
Extreme value analysis in the environmental sciences, with special reference to the analysis of extremes of wind speed and wave height for the UK and North Sea areas. *10th European Meeting of Statisticians, Leuven, Belgium.* 23 August.
Some links in the general circulation, with special reference to droughts in north-east Brazil and severe winters on the São Paulo Plateau. *Workshop/Seminar on Frost and Drought, Campinas, Brazil.* 6 September.
JOHNSON, D. A., Ph.D., A.R.C.S.
Measurement of droplet-size spectra. *European Research Office (US Army) Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 22 September.
JOHNSON, G. C.
British winter weather. *Recorded interviews for the BBC West African Service.* 4 and 10 February.
Mountain weather. *Three lectures to the Bremex Mountain Expedition Course, London Borough of Brent.* 23 February, 16 and 30 March.
JONAS, P. R., Ph.D.
Climatic effects of large-scale energy sources. *Colloquium on the Radiative and Thermal Balance of the Atmosphere, Meudon Observatory, France.* 7 April.
JONES, D. E., M.Sc., D.I.C., A.R.C.S.
Advances in forecasting techniques. *BBC Radio 4 (Scottish Region).* 6 April. *Interview for farming program, BBC TV.* 23 October.

MCALLEN, P. F.
The weather. *Recorded commentary for a series of adult education programs, Westward TV.* 3 and 4 October.
Tropical cyclones. *Interview on BBC Overseas Service.* 22 November.
Weather forecasting. *Commentary for one of a series of six adult education programs, Westward TV.* 8 December.
MCILVEEN, W. A., Ph.D.
Computers and weather forecasting. *Seminar at the Computer Science Department, University of Glasgow.* 1 November.
MCKELLAR, H.
The weather. *Lecture to the Publicity Club of Glasgow.* 3 March.
The weather. *Interview on BBC Radio 4 (Scotland).* 6 April.
MARSHALL, G. A.
Manchester Weather Centre. *Talk on Radio Merseyside.* 2 November.
MASON, B. J., C.B., D.Sc., F.R.S.
The atmospheres of the planets. *The Halley Lecture, University of Oxford.* 17 May.
Three lectures: (1) Numerical prediction of weather, (2) Climatic changes—modelling of climate, (3) Planetary atmospheres. *University of St Andrews.* 23, 24 and 25 May.
Climatic change. *University of Aberdeen.* 26 May.
Man's influence on weather and climate. *European Organization for Nuclear Research (CERN), Geneva.* 3 June.
Man's influence on the climate. *German Meteorological Society, Offenbach.* 13 September.
Climate and climatic change. *Sixth Form lecture organized by the Royal Meteorological Society's Education Committee, London.* 28 November.

Computer modelling of weather and climate. *Friday Evening Discourse, Royal Institution London.* 2 December.

Climatic change. *Lecture to course for Senior Meteorologists, Meteorological Office College, Shinfield Park.* 12 December.

MASON, P. J., Ph.D.

Interaction of topography and Ekman boundary layer pumping in a stratified atmosphere. *University of Reading.* 14 January.

MILES, M. K., M.Sc., A.R.C.S.

Atmospheric circulation during the 1975/76 drought. *Royal Meteorological Society Discussion Meeting on 'The Drought of 1976', Imperial College, London.* 19 January.

Rainfall variations in relation to climatic fluctuations. *Central Water Planning Unit, Reading.* 3 March.

MORRIS, R. M., B.Sc.

Eigenvectors. *Seminar at the Clarendon Laboratory, Oxford.* 3 March.

The sunless weather. *An interview on the current weather situation, London Broadcasting Company.* 21 June.

Offshore services. *Meeting of Marine Engineers, Port Talbot, West Glamorgan.* 22 June.

Weather forecasting. *Talk on 'Up to the Hour' program, BBC Radio 4.* 9 August.

Heavy rain in the London area. *Talk for London Broadcasting Company.* 17 August.

Rainfall in Wales. *Talk on BBC TV (Wales).* 25 August.

Quasi-dynamical methods in weather forecasting. *Lecture to the Senior Meteorologists' Course, Meteorological Office College, Shinfield Park.* 19 December.

MURGATROYD, R. J., O.B.E., Ph.D., C.Eng., M.I.E.E.

UK studies of the stratosphere and the possible effects of stratospheric pollution. *UNEP World Plan of Action on the Ozone Layer, Washington, D.C.* 2 March.

Stratospheric modelling—some recent developments. *Seminar preceding meeting on Tripartite Agreement on Stratospheric Modelling, between France, UK and USA, Paris.* 22 March.

Processes determining stratospheric composition. *The Photobiology Society, Imperial College, London.* 1 June.

UK modelling studies of the ozone depletion problems. *First Meeting of the Co-ordination and Study Groups on the Ozone Shield Depletion Problems, Commission of the European Communities, Brussels.* 25 October.

UK research in relation to the UNEP plan of action on the ozone layer. *UNEP Co-ordinating Committee on the Ozone Layer, Geneva.* 2 November.

NEWSON, R. L., B.A.

Studies of stratospheric warmings simulated by a general circulation model (text by A. O'Neill, B.A. and R. L. Newson). *IAMAP Conference, Seattle, Wash.* 22 August–3 September.

OGDEN, R. J., B.Sc.

Computers and meteorology. *Department of Systems and Computing, North-east London Polytechnic, Dagenham.* 26 January.

Lectures on weather and climate, surface wind, and on working overseas. *Royal Meteorological Society course on 'Meteorology for Civil Engineering and Building', University of Reading.* 24–25 March.

Weather and climate in relation to horticulture. *Conference of Produce Packers' Marketing Association, Coventry.* 13 May.

Meteorology and the offshore industry. *Special Topic lecture following the annual meeting of the Advisory Committee on Meteorology for Scotland, Edinburgh.* 17 May.

PAINTING, D. J., B.Sc.

Wind design criteria. *Joint Seminar, Royal Meteorological Society/Society for Underwater Technology, London.* 10 March.

Automatic weather buoys. *Society of Electronic and Radio Technicians, Reading.* 18 April.

PARTINGTON, S. J. G.

Day-to-day work of the Meteorological Office, Belfast. *Contribution to 'Up-country' program, BBC Northern Ireland.* 14 January.

Meteorological data for teachers and students. *Stranmillis Teachers' Training College, Belfast.* 4 July.

PONTING, J. F., M.A., M.Sc. and WILEY, R. L., Ph.D.
Real-time processing of image data from satellites under RSX11–D. *Digital Equipment Computer Users Society (DECUS) Europe Symposium, London.* 7 September.

RATCLIFFE, R. A. S., M.A.
The drought of 1975/76.
Royal Meteorological Society Discussion Meeting on 'The Drought of 1976', Imperial College, London. 19 January.
Royal Meteorological Society Symposium, University of Nottingham. 2 February.
Climatic change. *Ascot and District Rotary Club, Berks.* 2 March.
Seasonal forecasting research. *Contribution to the Jimmy Young program, BBC Radio 2.* 28 March.

RIDDAWAY, R. W., Ph.D.
The use of computers for weather forecasting. *University of Aston in Birmingham.* 8 February.

ROACH, W. T., Ph.D., D.I.C.
Radiative processes in cloud physics. *European Research Office (US Army) Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 22 September.
Some aspects of radiative transfer in cloud physics. *Department of Meteorology and Geophysics, University of Reading.* 14 October.

ROWNTREE, P. R., Ph.D.
Numerical modelling experiments relevant to the drought summer of 1976. *Royal Meteorological Society Discussion Meeting on 'The Drought of 1976', Imperial College, London.* 19 January.
The effects of changes in ocean temperature on the atmosphere. *JOC/SCOR Study Conference on General Circulation Models of the Ocean and their Relation to Climate, Helsinki.* 26 May.
Tropical Pacific sea temperature anomalies of July 1972 and their effects on model and real atmospheres. *Internal Seminar, Geophysical Dynamics Laboratory, NOAA, Princeton, N.J.* 22 July.
Six lectures: (1) The Synoptic-scale Sub-program Data Centre's analysis of the mean GATE Phase 3 atmosphere, (2) General circulation model simulations of the GATE area atmosphere, (3) Soil moisture experiments with a tropical model, (4) The UK Meteorological Office tropical model—outline and results, (5) Convection, radiation and cloud parametrizations in the UK Meteorological Office tropical model, (6) The current status of numerical simulations and predictions in the GATE area. *US Central GATE Workshop, Boulder, Col.* 25 July–12 August.

ROY, MARJORY G., M.Sc.
Soil moisture and temperature conditions at five climatologically contrasting sites in the UK in relation to grass production. *Joint Meeting, British Grassland Society/Society of the Chemical Industry, London.* 18 October.

RYDER, P., Ph.D.
The current pattern of cloud physics research. *Royal Meteorological Society Review Meeting on 'Cloud Physics Research', Imperial College, London.* 14 December.

SANDS, K. J. T.
Automatic weather recording systems. *Course for ADAS Staff, Meteorological Office College, Shinfield Park.* 8 March.
Automatic weather stations and buoys. *European Research Office (US Army) Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 23 September.

SCOTT, J.
The organization of forecasting services and communications with the public. *Course for ADAS Staff, Meteorological Office College, Shinfield Park.* 7 March.
Meteorology for civil engineering and the building industry. *Royal Meteorological Society course, University of Reading.* 7 March.
Comparison of UK and USA TV weather presentations. *Participation in 'Nationwide' program, BBC TV.* 27 September.

Weather presentation on television. *Live presentation and interview on 'Nationwide' program, BBC TV.* 18 October.

SHAW, D. B., B.Sc.

Numerical prediction experiments in the monsoon region. *International Symposium on Monsoons, New Delhi.* 10 March.

SINGLETON, F., B.Sc., D.I.C.

A course in meteorology for sailors.
Scout Association Training Centre, Marlow, Bucks. 26 and 27 February.
National Sailing Centre, Cowes. 3 December.

The use of satellites in weather forecasting. *Public lectures at University of East Anglia.* 24 and 25 March.

The use of satellites in operational meteorology. *Society for Underwater Technology, London.* 29 September.

Weather forecasting—a marriage of science and technology. *Van Leer Research Laboratories, Liphook, Hants.* 11 October.

SMITH, C. V., M.A., B.Sc.

Work days from weather data. *Autumn National Conference, Institution of Agricultural Engineers, Colchester.* 11 October.

Six lectures: (1) Agricultural production, (2) Land use planning, (3) Crop storage, (4) Plant disease forecasting, (5) Weather and animal diseases, (6) Animal housing. *WMO/FAO Technical Conference on the Potential Economic Benefits of Agricultural Meteorology, Rome.* 17–21 October.

SMITH, F. B., Ph.D.

Boundary layer and dispersion. *Lectures to the M.Sc. course, University of Surrey, Guildford.* 3, 10 and 17 February.

Procedures in case of accidental release of pollutants. *Atomic Energy Research Establishment, Harwell.* 16 February.

Two lectures: (1) Structure of the atmospheric boundary layer, (2) Atmospheric transport and deposition. *Central Electricity Research Laboratories, Leatherhead, Surrey.* 28 April and 26 May.

Deposition rates of sulphur dioxide implied by aircraft measurements over the North Sea. *Royal Meteorological Society Discussion Meeting on 'Atmosphere–Surface Exchanges of Pollution', Imperial College, London.* 15 June.

Transport of sulphur pollutants. *European Research Office (US Army) Panel on Meso-Meteorology, Meteorological Office College, Shinfield Park.* 22 and 23 September.

Transfrontier air pollution. *Seminar for Industry, organized by the Department of the Environment, London.* 14 October.

Pathways of pollution in the atmosphere. *Royal Meteorological Society, London.* 27 October.

Techniques in estimating dispersion. *National Radiological Research Laboratories, Harwell.* 23 November.

SMITH, K. C.

Weather and agriculture. *Mark Agricultural Discussion Group, Somerset.* 2 February.

SPALDING, T. R., B.Sc.

Mountain weather. *Royal Meteorological Society Field Course, Betws-y-Coed, Gwynedd.* 3–10 August.

SPARKS, W. R., B.Sc.

Climatic change. *Vale Farmers' Discussion Group, Stroud.* 24 January.

The drought of 1976. *South Devon Farmers' Discussion Group, Exeter.* 23 February.

STARR, J. R., Ph.D.

Clouds, rain and rainmaking.
Two Sixth Form lectures, Lancaster Branch of the Institute of Physics, Preston Polytechnic. 10 January.
Physical Society, University of Leeds. 18 November.

Flukes, frost, calves and crops.
Newbury Young Farmers' Club. 22 March.
Polymer Society, Polytechnic of Central London. 24 March.

Agricultural meteorology in the Meteorological Office. *Hadlow College, Kent.* 24 November.

STEWART, J. B., B.Sc., D.I.C.

Interception of rainfall. *Royal Meteorological Society Summer Meeting, University of Lancaster.* 22 July.

THOMPSON, N., Ph.D.

The chemical threat to civilian populations. *Home Office Defence College, Easingwold, N. Yorkshire.* 11 March.

Two lectures: (1) The structure of convective boundary layers, (2) Fluxes and spectra in the GATE sub-cloud layer. *Royal Meteorological Society Specialist Group on Air–Sea Interaction, Imperial College, London.* 22 March.

TODD, J. K.

Local weather forecasting. *Wardens' Training Course, Lake District National Park, Ambleside.* 8 February.

TUCK, A. F., Ph.D.

A comparison of one-, two- and three-dimensional model representations of the behaviour of stratospheric gases. *Royal Society Discussion Meeting, London.* 3 and 4 November.

TYLDESLEY, J. B., B.A.

Atmospheric processes. *Ten lectures to Second Year B.Sc. students, Departments of Earth Sciences, Geology and Geography, University of Leeds.* March–May.

WATSON, N. R.

Stratospheric analysis. *Department of Physics, Heriot-Watt University, Edinburgh.* 24 January.

The stratospheric sounding unit on the TIROS–N satellite and the proposed use of its data. *Institute of Meteorology, Free University, Berlin.* 23 May.

WEBBER, K. L., Ph.D.

Cumulus interaction with the sub-cloud layer. *Royal Meteorological Society Specialist Group on Air–Sea Interaction, Imperial College, London.* 22 March.

Fluxes and spectra in the GATE sub-cloud layer. *Max-Planck Institut für Meteorologie, Hamburg.* 3 May.

Fluxes and spectra obtained during GATE. *US Central GATE Workshop, Boulder, Col.* 25 July–12 August.

WHITE, G. A.

Marine meteorological services to shipping. *International Safety at Sea Symposium, London.* 13 October.

WHITE, P. W., Ph.D.

The Meteorological Office model comparison experiment. *Reading University.* 3 October.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. Catalogues listing all the publications which may be purchased through the sales office or usual agents of Her Majesty's Stationery Office, or direct from the Meteorological Office at Bracknell, are sent free to any applicant.

The following publications have been issued:

PERIODICALS

Annual Report on the Meteorological Office 1976.

Daily Aerological Record containing information in respect of meteorological conditions in the upper air for the British Isles.

Daily Weather Report containing weather maps for the northern hemisphere, British Isles etc., and data.

Monthly Summary of the *Daily Weather Report.*

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for the United Kingdom, the weather of the past month, a general survey and inference, and weather prospects for the coming month in the United Kingdom; a supplementary document, containing survey, inference and prospects only, is published in mid month.

Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain, a seasonal fortnightly publication providing estimates of soil moisture deficit in map form and as a tabular statement for river authority areas.

Sea Ice Charts (daily).

Monthly (coloured) *Ice Maps* (to August 1977).

Meteorological Magazine (monthly).

Monthly Weather Report (to February 1977).

Marine Observer (quarterly).

SERIAL

Geophysical Memoirs:

Volume XVII

120. Average temperatures, contour heights and winds at 30 millibars over the northern hemisphere, by R. A. Ebdon.
121. Bumpiness in clear air and its relation to some synoptic-scale indices, by W. R. Sparks, B.Sc., S. G. Cornford, M.Sc. and J. K. Gibson, G.I.M.A.

Scientific Papers:

34. The Meteorological Office operational 10-level numerical weather prediction model (December 1975), by D. M. Burridge, Ph.D. and A. J. Gadd, Ph.D.
36. A computer-based model for design rainfall in the United Kingdom, by J. F. Keers, B.Sc. and P. Wescott.
37. The variability of long-duration rainfall over Great Britain, by R. C. Tabony B.Sc.
38. The psychrometer coefficient of the wet-bulb thermometers used in the Meteorological Office large thermometer screen, by C. K. Folland, B.Sc.

OCCASIONAL

The Marine Observer's Handbook, 10th edition (1977).

APPENDIX IV

ACRONYMS AND ABBREVIATIONS

AAFCE	Allied Air Forces Central Europe
ACRE	Automatic Climatological Recording Equipment
ADAS	Agricultural Development and Advisory Service
AFCENT	Allied Forces Central Europe
AGARD	Advisory Group on Aerospace Research and Development
ASP	Asymmetric Multiprocessing System
ATWS	Automatic Telephone Weather Service
AUTOCOM	Automated Telecommunication Complex
AVHRR	Advanced system of Very High Resolution Radiometers
AWS	Automatic Weather Station
CAMFAX	Civil Aviation Meteorological Facsimile Network
CARD	Continuous Automatic Remote Display
CBR	Cloud Base Recorder
CBS	Commission for Basic Systems (WMO)
CDF	Coded Digital Facsimile
CENTO	Central Treaty Organization
CFO	Central Forecasting Office
CMM	Commission for Marine Meteorology (WMO)
CNRS	Centre National de Recherche Scientifique
COM	Computer Output on Microfilm
CoSAMC	Commission for Special Applications of Meteorology and Climatology (WMO)
COSMOS	Meteorological Office computing system
COSPAR	Committee for Space Research (ICSU)
COST	European Co-operation in Science and Technology
CRDF	Cathode Ray Direction Finding
DALE	Digital Anemograph Logging Equipment
DB	Data Buoy
DEC	Digital Equipment Corporation
EC	Executive Committee (WMO)
ECMWF	European Centre for Medium-range Weather Forecasts
EEC	European Economic Community
ESA	European Space Administration
FAO	Food and Agriculture Organization of the United Nations
FGGE	First GARP Global Experiment (WMO/ICSU)
GARP	Global Atmospheric Research Program (WMO/ICSU)
GATE	GARP Atlantic Tropical Experiment (WMO/ICSU)
GDPS	Global Data Processing System (WMO)
GMT	Greenwich Mean Time
GOS	Global Observing System (WMO)
GTS	Global Telecommunication System (WMO)
IAMAP	International Association of Meteorology and Atmospheric Physics (IUGG)

IBM	International Business Machines Ltd
ICAO	International Civil Aviation Organization
ICL	International Computers Ltd
ICSU	International Council of Scientific Unions
IEA	International Energy Agency (OECD)
IMCO	Inter-Governmental Maritime Consultative Organization
ISO	International Organization for Standardization
ITE	Institute of Terrestrial Ecology (NERC)
IUGG	International Union of Geodesy and Geophysics (ICSU)
IUTAM	International Union of Theoretical and Applied Mechanics (ICSU)
JASIN	Joint Air–Sea Interaction Experiment (Royal Society)
JES3	Job Entry Sub-system 3
JOC	Joint GARP Organizing Committee (WMO/ICSU)
LORAN	Long Range Navigation System
LCBR	Laser Cloud Base Recorder
MAFF	Ministry of Agriculture, Fisheries and Food
MCMG	Military Committee Meteorological Group (NATO)
MOD(N)	Ministry of Defence (Navy Department)
MOD(PE)	Ministry of Defence (Procurement Executive)
MOLFAX	Meteorological Office Land-line Facsimile Network
MONEX	Monsoon Experiment, India (GARP/ICSU)
MOWOS	Meteorological Office Weather Observing System
MRF	Meteorological Research Flight
MTC	Main Trunk Circuit
MTER	Magnetic Tape Event Recorder
MVS	Multiple Virtual Storage
MVT	Multiprogramming system with a Variable number of Tasks
NAOS	North Atlantic Ocean Stations
NASA	National Aeronautics and Space Administration, USA
NATO	North Atlantic Treaty Organization
NAVAID	LORAN–C navigational system
NERC	Natural Environmental Research Council
NESS	National Environmental Satellite Service (NOAA)
NMC	National Meteorological Centre
NOAA	National Oceanic and Atmospheric Administration, USA
NORSWAM	North Sea Wave Model
NWS	National Weather Service (NOAA)
ODAS	Oceanic Data Acquisition System
OECD	Organization for Economic Co-operation and Development
OWS	Ocean Weather Ship, Ocean Weather Station
PCK	Processor-Controlled Keying
PEPR	Precision Encoding and Pattern Recognition
PTRC	Planning and Transport Research and Computation (International) Co. Ltd
RAE	Royal Aircraft Establishment
RAF	Royal Air Force
RCA	Radio Corporation of America, Princeton, N.J.

RMC	Regional Meteorological Centre
RNAS	Royal Naval Air Station
RSRE	Royal Signals and Radar Establishment
RTH	Regional Telecommunication Hub
SCODS	Standing Committee on Ocean Data Systems (NERC)
SCOR	Scientific Committee on Oceanic Research (ICSU)
SDB	Synoptic Data Bank
SEOCS	Sun, Earth Observatory and Climatology Satellite
SHAPE	Supreme Headquarters of Allied Powers in Europe
SR	Scanning Radiometer
SSU	Stratospheric Sounding Unit
TSO	Time-Sharing Option
TTO	Telecommunication Technical Officer
UK	United Kingdom
UKOAA	United Kingdom Offshore Operators Association
UNEP	United Nations Environment Program
Unesco	United Nations Educational, Scientific and Cultural Organization
URSI	International Union of Radio Science (ICSU)
USA	United States of America
VAP	Voluntary Assistance Program (WMO)
VDU	Visual Display Unit
VHRR	Very High Resolution Radiometer
VS2	Virtual Storage System
VTPR	Vertical Temperature Profile Radiometer
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)

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